POWER PLANT ENGINEERING

Established Over 29 Years

VOL. XXIX CHICAGO, JULY 1, 1925 No. 13

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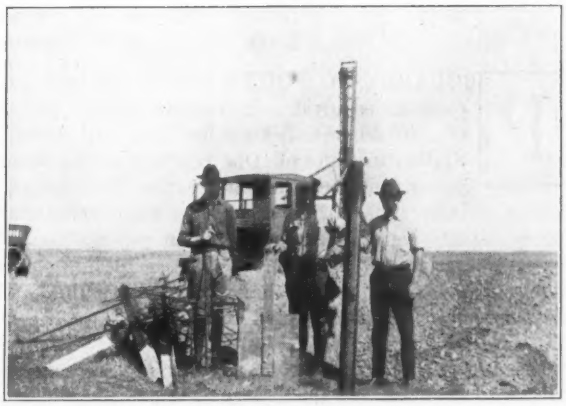
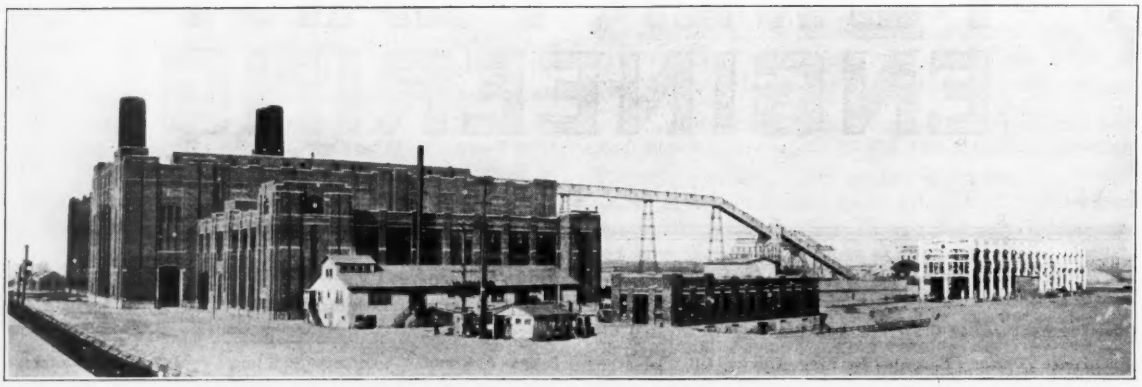


Dry Ground Is a Poor Ground

JUDGING FROM the wide expanse of territory shown in the above photograph, this construction crew should experience no great difficulty in finding a good ground—there seems to be plenty of it as far as the eye can reach. This is out in California and they are installing a ground plate for use on the 220,000-v lines of the Pacific Gas & Electric Co. A lot of ground, however, does not always signify a good ground for frequently the ground is dry, making it a poor conductor of electricity. In such instances, the question of securing a good ground presents real engineering problems and elaborate precautions are often necessary to secure a connection of permanent low resistance. What these problems are and how they may be solved are more fully discussed in the article on Outdoor Substations appearing in the pages of this issue.

IT ROTATES, yet it stands still. This seeming paradox is one of the first things that comes to mind when the theory of the induction motor is explained for the first time. How can a rotating field result from a set of stationary poles? Still more difficult to conceive in the action of this motor is the manner in which this rotating field reacts with the field of the rotor to produce rotation. Both of these things are explained in a new light in an article by Charles G. Green on page 701.



Engineering Features of Crawford Ave. Station

LATEST ADDITION TO CHICAGO'S ELECTRICAL SYSTEM WILL HAVE AN ULTIMATE CAPACITY OF OVER 750,000 KILOWATTS

PROBABLY NO POWER station ever built has commanded greater interest during the period of its construction than has Crawford Avenue Station in Chicago. One year ago at the world power conference held in London, England, engineers from over the entire world met to discuss engineering problems. Naturally, many different topics came up for consideration and the engineers from each country had their particular problems at heart, yet on one thing all seemed to find common ground for discussion; that one thing was Crawford Avenue Station of Chicago. It was known to everybody and its details interested not only the American engineers but the foreign delegates as well.

Crawford Avenue Station, which was formally opened on May 26, is the latest addition to the Commonwealth Edison Company's system in Chicago, and with its highly efficient equipment and a projected capacity of 750,000 kw. will for some years to come be the most important of the five large stations now in operation on that system.

Its engineering features are at once spectacular and conservative, spectacular because of its enormous capacity and startling variation in the design of its equipment as compared to that installed in other stations and conservative because of the thoroughness with which each detail of its design was studied.

One reason perhaps for the international interest this station has commanded is the installation of two American built turbo-generators of different make side by side with a Parsons unit built in England. This is one of the few cases where a foreign built machine of large capacity is installed in America and this fact naturally augmented the interest of foreign engineers.

GENERAL FEATURES OF THE STATION

Crawford Avenue Station is located on the west side of Chicago near the city limits at Crawford Avenue and the Sanitary District Canal. The property which comprises 72 acres provides space for an ultimate storage of over 300,000 T. of coal, although the storage capacity at the present time is only 100,000 T. An ample supply of cooling water for condensing purposes is available from the canal which forms the south boundary of the property and excellent railroad facilities are afforded by the Illinois Central Railroad and the Chicago and Illinois Western Roalroad which run adjacent to the site on the north, the Illinois Northern Railroad on the east and the Atchison, Topeka and Santa Fe

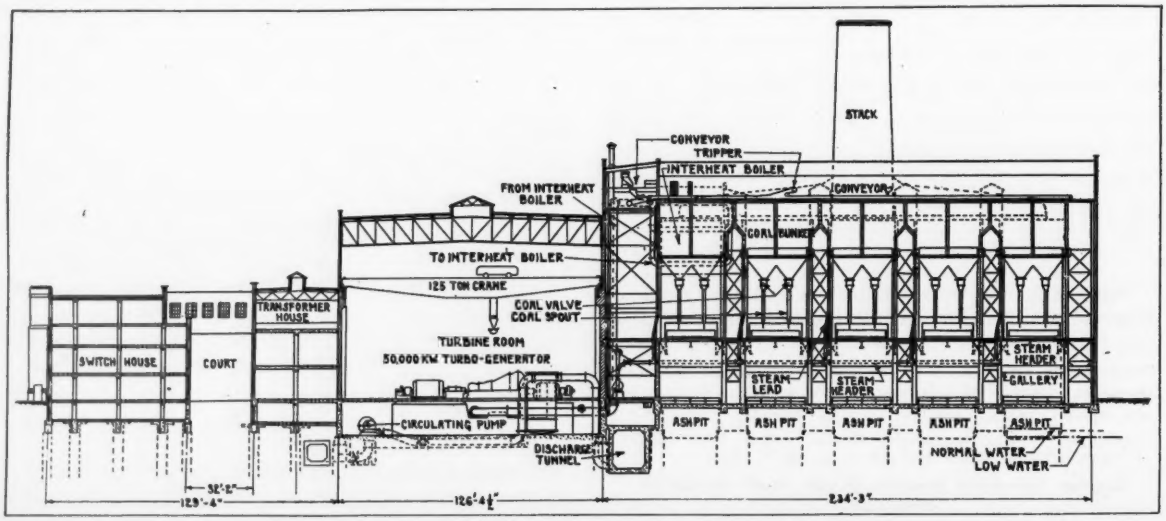


FIG. 1. GENERAL CROSS SECTION THROUGH CRAWFORD AVE. STATION

Railroad, the main line of which runs along the opposite side of the drainage canal.

Ground for this plant was first broken in March, 1923, the first turbine unit was placed in operation in November, 1924, some 20 months later. One of the preliminary operations was the removal of 250,000 cu. yd. of earth thrown up as a spoil bank in the construction of the canal. Another important part of the work, not evident from a casual examination of the property, was the construction of a tunnel under the canal for part of the high voltage underground cables leading to and from the plant. Throughout, the excavating operations were enormous.

A general plan of the property is shown in Fig. 3 on which is shown the plan of the first section of the buildings.

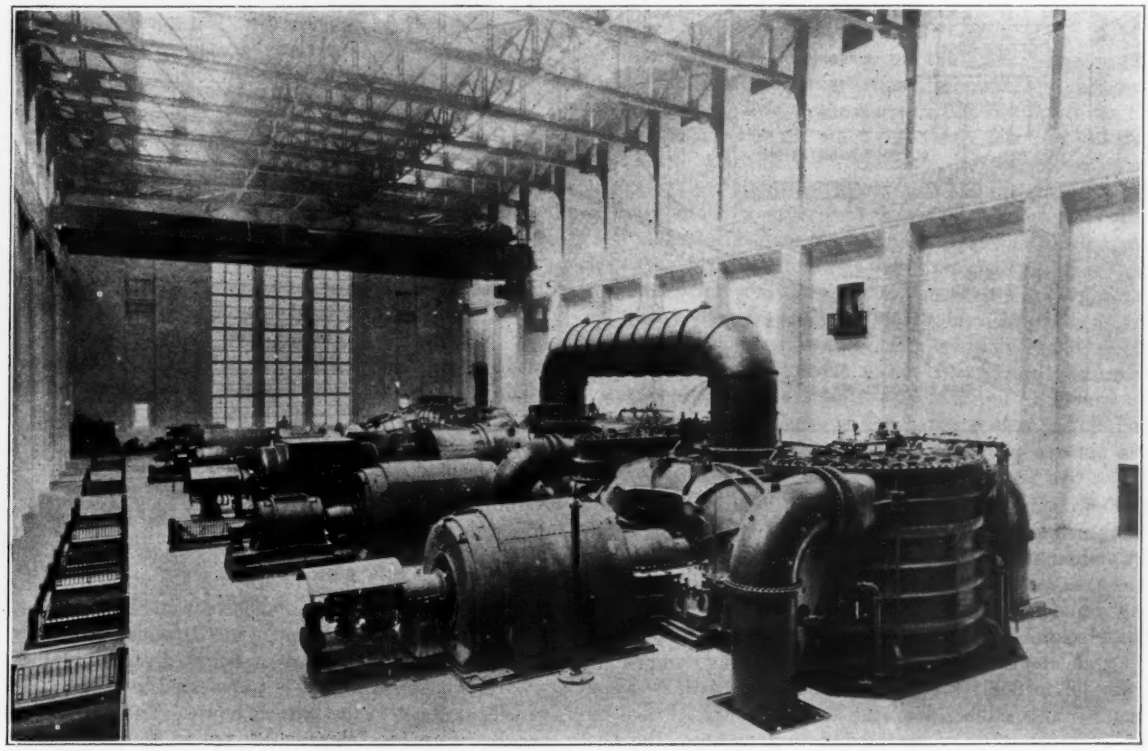


FIG. 2. THE TURBINE ROOM, LOOKING WEST

This first section represents 40 per cent of the ultimate building and the 160,000 kw. in generating units in operation at present is 21 per cent of the projected capacity. As additional sections are added, the station will be extended towards the east, the first section, as will be noted, forming the west end of the ultimate building.

The buildings are supported by 315 concrete piers carried down to bed rock approximately 75 ft. below ground level. The foundations for the turbo-generator units and auxiliary equipment rest on a four foot concrete slab spread over the entire turbine room basement, 17 ft. below ground level. All buildings are of massive construction, the exteriors being faced with large red pressed paving brick and trimmed with white stone. The turbine room and boiler house occupy the main building which is 332 ft. long, 363 ft. wide and 100 ft. in height. Two steel plate, brick lined stacks, 26 and 30 ft. in diameter extend 90 ft. above the boiler house roof. The switchhouse located to the south of the main building is 211 ft. long by 68 ft. wide, while an intermediate building, the transformer house, is 300 ft. long, 41 ft. wide with the roof 50 ft. above ground. These dimensions are for the present section only.

Condensing water is drawn from the Sanitary District Canal through an open intake flume to the crib house where are installed the revolving water screens, and then to the condensing apparatus in the turbine room through a concrete tunnel 12 ft. square. The discharge tunnel, which is located to the west of the intake tunnel, is also of concrete, 18 ft. high by 16 ft. wide. The bottoms of all tunnels are 33 ft. below the ground level. Due to the fact that the Drainage Canal carries the sewage from practically the entire city of Chicago, the water contains an exceedingly large quantity of suspended matter and, for this reason, the water screens form a highly important link in the circulating water system. Twelve Link-Belt Co. revolving screens are installed in sets of two, arranged in series. These are driven by 5 hp., 440 v., Westinghouse motors, and are equipped with high pressure washing sprays.

Eastward of the crib house is located the outdoor transmission substation. This is a concrete structure, 290 ft. long and 45 ft. wide, designed to accommodate seven 15,000 kw. transformers together with all necessary switching equipment, busses and connections. Five of the transformers are now in service, receiving energy from the station at 12,000 v. and stepping up to 33,000 v. for transmission to other stations over 3-conductor underground tie-lines. All of the transformers in this structure are equipped with ratio adjusters which may be operated under load. This is one of the first outdoor substation structures ever built entirely of concrete and is more attractive architecturally than the usual steel structure.

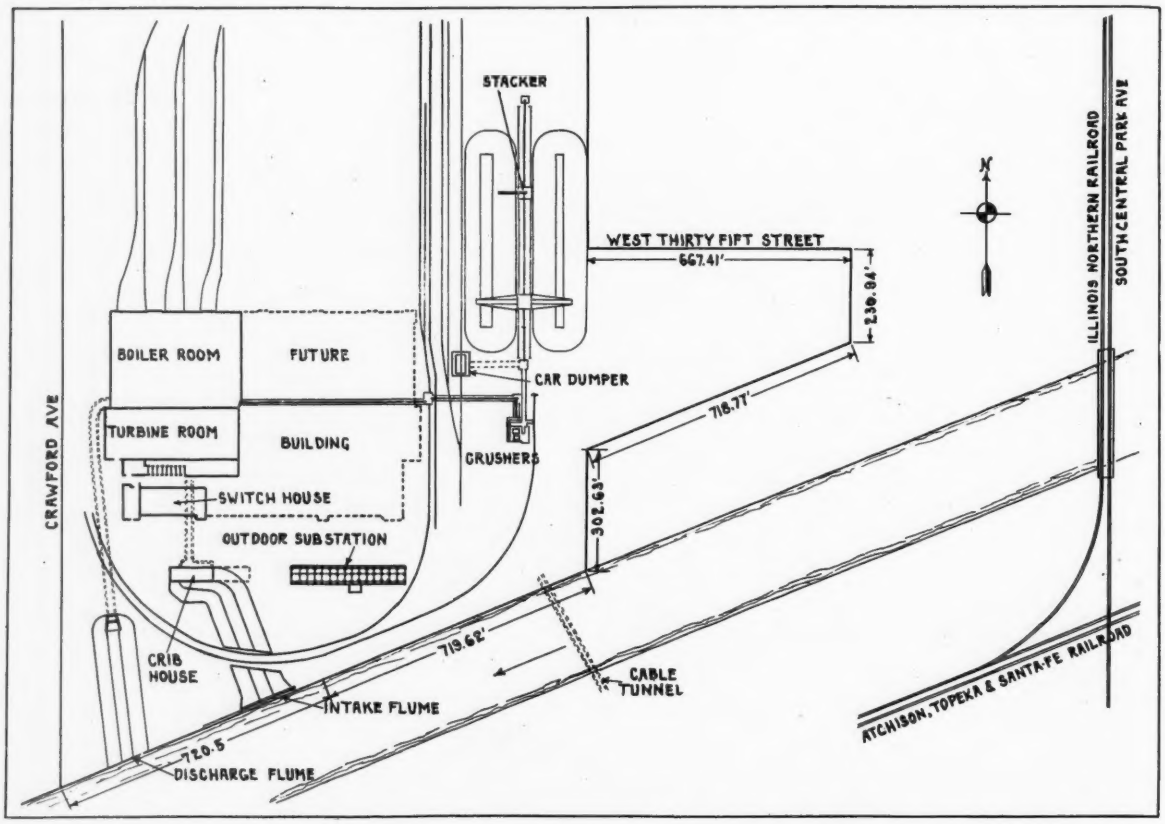


FIG. 3. THE PROPERTY WHICH COMPRISES 72 ACRES PROVIDES FOR AN ULTIMATE STORAGE OF OVER 300,000 T. OF COAL

Coal is delivered to the property in railroad cars and whether intended for storage or for immediate use enters the system at the same point. All cars are emptied by an electrically operated rotary car dumper to which they are pulled by means of a motor operated mechanical car puller. The platform of this car dumper constitutes the platform of a scale and each car is weighed before being dumped and again immediately after being dumped. In this way an accurate determination of the exact amount of coal received is obtained. After having been dumped, the next car to be emptied pushes the empty down a gravity track and over a "kick back" which allows it to return on a track parallel to, but at a lower level than the loaded cars entering the dumper.

From the receiving hopper beneath the dumper the coal is delivered to a belt conveyor by means of a reciprocating feeder. This feeder is operated by a two speed motor and is fitted with an adjustable eccentric so that both the speed and the length of stroke may be regulated to suit the requirements of the coal breaker. Some coals cannot be fed to the breaker as fast as others and for this reason it is desirable that the speed of delivery be under control.

From the belt conveyor the coal can be taken either to the storage piles in the yard, or delivered directly to the breakers for immediate use in the plant, or, if desired, to both the storage piles and the breaker simultaneously. Storage coal is transferred from the first conveyor to a storage conveyor running at right angles out into the coal yard, which delivers it to a traveling tripper and stacker, which piles the coal on either side of the conveyor.

Coal is reclaimed from the storage piles by a gantry crane equipped with a 2½ T. clamshell bucket. When reclaiming, the bucket delivers the coal back on the belt, the direction of which is reversed and is in turn carried to the coal breakers. Both the gantry crane and the stacker travel the entire length of the storage space.

When the coal is not intended for storage, it leaves the hopper under the car dumper in the same manner as described above, but instead of being diverted to the left towards the storage piles, is transferred to a belt conveyor which carries it to the breaker house. The latter contains two Bradford breakers, each driven by 150 hp., 440 v., 60 cycle, Westinghouse, type CW., slip-ring motors. From the breakers, the coal is carried up an inclined conveyor and then by means of a long belt running in an enclosed housing supported on steel towers, is delivered to the upper part of the boiler house.

Coal which cannot be reduced to the proper size in the Bradford breaker is passed out through the end of the cylinder and crushed in a small roll crusher.

All conveying belts used in the system were furnished by the Koppers Co. of Pittsburgh, the car dumper by the Wellman, Seaver, Morgan Co. while the stacker and gantry crane is Meade-Morrison equipment. The Bradford breakers were furnished by the Pennsylvania Crusher Co.

Motors driving the coal handling equipment outside of the boiler room proper are 440 v., 3 phase, alternating current machines. It is not deemed advisable to use a higher voltage for this class of service, although in the power plant 2300 v. motors are used for practically all heavy duty service. The car dumper is operated by a 50 hp., G. E. motor, controlled by a hand operated drum controller. The various conveying belts and other coal handling machinery are all arranged for push button

control and the machinery is so interlocked that the various parts of the system can only be started in the proper sequence. Although the entire system can be shut down from one "stop" push button, the component parts can only be started from push buttons located in the immediate vicinity of the driving motors.

In the boiler room, the coal is tempered by means of a water spray installed over the incoming conveyor and is then delivered to two distributing belt conveyors installed above each row of coal bunkers. These belts are fitted with traveling trippers which distribute the coal uniformly in the bunkers below from which it is fed by gravity to the stokers through spouts.

Each overhead bunker has a capacity of 250 T. and serves two boilers, one on each side of the firing aisle. They are of steel, lined with concrete and are provided with four delivering spouts, two leading to each stoker.

The capacity of the conveyors feeding into the building is 400 T. per hour.

Five Boilers Generate Steam for One Turbine

Steam is generated in 15 Babcock and Wilcox Co. boilers, twelve of which are standard water tube boilers and three are reheat boilers provided for the purpose of reheating the steam after expansion in the high pressure turbines. Two of the reheat boilers are in operation and the third is to be installed at a later time. All boilers are equipped with Diamond Soot Blowers.

As shown on the plan, the boilers are arranged in three rows of five each, each row connecting to one main steam header for each turbine unit. Thus five boilers are provided for each unit, four standard boilers and one reheat boiler. The main headers, however, are connected by cross ties which permit any combination of boilers desired.

The standard boilers are built to operate at a maximum pressure of 650 lb. gage with a maximum total temperature of 750 deg. Each has a heating surface of 16,615 sq. ft. arranged in two banks, a lower bank of eight rows of 3¼ in. tubes, 15 ft. long exposed for their full length above the furnace and an upper bank of 17 rows of 2 in. tubes over which the gases make two passes. The superheater is placed between the two banks of tubes, as shown in Fig. 7. The gases pass between nipples connecting the upper and lower parts of the downtake headers and flow downward over an economizer. The headers are of wrought steel and the tubes are so spaced that there are diagonal lanes between all of the tubes through which the exterior of the tubes may be thoroughly cleaned. The economizers are of the counter flow type, made of wrought steel, with the tubes inclined slightly upwards. The economizer surface is 11,054 sq. ft. or 66.6 per cent of the boiler heating surface. These boilers are rated to evaporate 150,000 lb. of water per hr. as a maximum, corresponding to 9 lb. per hr. per sq. ft. of boiler heating surface. The furnace volume is 5910 cu. ft.

Five of the boilers, those on the Parsons generating unit, in addition to having economizers, are equipped with air preheaters. Two of these are of Babcock & Wilcox Co. manufacture, while the other three were made by the Buffalo Forge Co. If the installation of these preheaters proves successful from an economic standpoint, they can easily be added to other boilers.

The reheat boilers whose main function is to reheat the exhaust steam from the high pressure turbines, also produce steam—only a relatively small amount, however. The boiler proper contains 6000 ft. of surface, while the reheater, which is mounted on top, contains 14,000 sq. ft. The boiler produces about 65 to 70 per cent as much steam as each of the standard boilers and is so proportioned that the furnace is the same under both types. They have steaming capacities of 96,500 lb. per hr. and reheating capacities of 480,000 lb. of steam per hr.

The stokers under the reheat boilers are operated so as to regulate the temperature of the steam leaving the reheater, and the primary object of the boiler under the reheater is to reduce the temperature of the furnace gases to a value under 1700 deg. F. before they come in contact with the superheater surface. The tubes in the reheater,

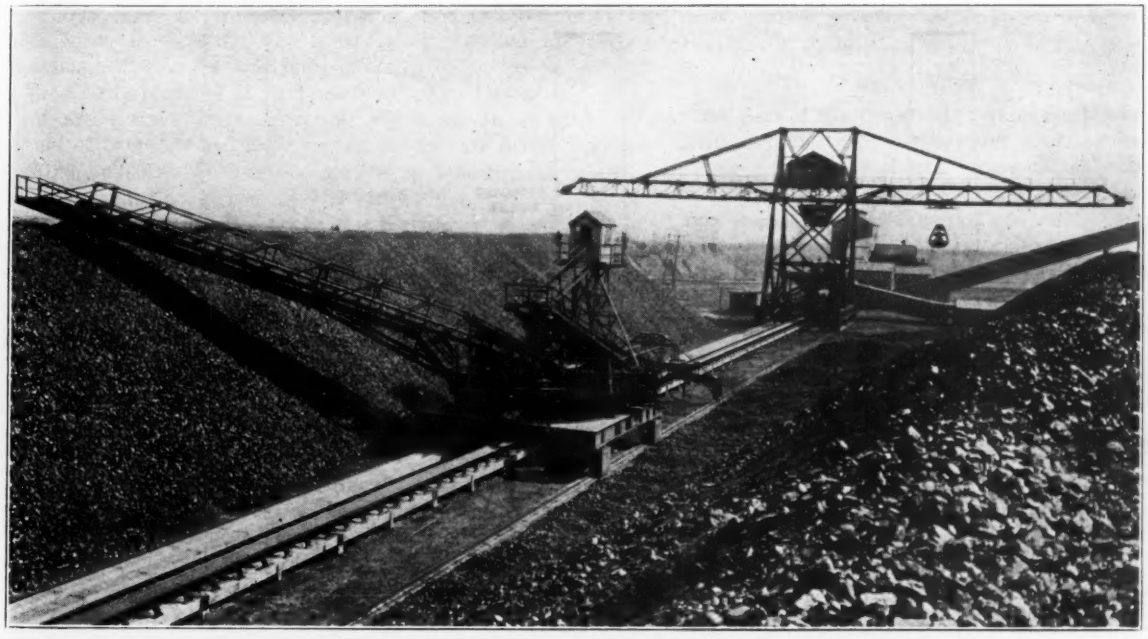


FIG. 4. COAL STORAGE AND RECLAIMING EQUIPMENT

of course, contain only dry steam and if they were to come in contact with gases having the temperature of the furnace, the results would be disastrous.

To prevent overheating of the reheater tubes in case the steam supply is cut off, due to the intercepting valve on the turbine closing, the reheat boiler is provided with a number of air admission doors. These are of the Chapman electrically operated type and are controlled from both the boiler and turbine room.

Three Makes of Stokers Used

All boilers, standard and reheat, are fired with forced draft, chain grate stokers. Those on the five boilers serving the Parsons unit are Illinois stokers, having 423 sq. ft. of effective grate area, those on the five serving the General Electric unit are B. and W. stokers with an area of 444 sq. ft., while the remaining five serving the Westinghouse turbine are Coxe stokers with 423 sq. ft.

All stokers are driven by 5 hp., 230 v., direct current Westinghouse motors, two motors being required for each stoker. This method of drive is required because of the great width of the stokers. Both motors are controlled by a single controller and are normally supplied from a motor generator set with provision for emergency throw over to the storage battery.

Forced draft is supplied to each stoker by two 40,000 cu. ft. per min. Buffalo Forge Co. fans, driven by 25 hp., 2300 v. variable speed Westinghouse motors, controlled from the boiler control panel. Westinghouse type S drum controllers operated by 1/6 hp., 230 v., d. c. motors are used for this purpose.

The induced draft fans, each of which is capable of removing 115,000 cu. ft. of flue gas per min. at a temperature of 325 deg. with a draft of 5½ in. of water, are installed in the upper part of the boiler room above the economizers. Three types of fans are used, five are Green Fuel Economizer Co. units, five are Sturtevant cinder-vane fans, and the remaining five are Sturtevant multivane units. Like the forced draft fans, the induced draft fans are also motor driven and are controlled by push buttons from the boiler control panel. The motors are rated at 150 hp.

An interesting feature of the system is that the forced draft fan motors are so interlocked with the induced draft fan motors that the former cannot be operated unless the latter are in operation. This is accomplished by the simple expedient of connecting both the induced draft fan motors and the forced draft fan motors on the line side of the induced draft fan starting switch. Unless the induced draft fan motor is running, the circuit to the forced draft fan motors will not be energized.

In addition to the induced and forced draft fans, each boiler is provided with a Sturtevant auxiliary air fan which supplies auxiliary air over the fuel bed to aid in the combustion of volatile gases distilled from the fuel.

Control of the boilers is effected by means of individual gage board containing the following equipment:

2 steam gages
1 feed water pressure gage
2 Bailey multiple forced draft gages
1 Bailey indicating steam flow meter
1 Bailey boiler meter (recording steam flow and air flow)
1 stoker controller
Push button controls for the induced draft, forced draft and auxiliary draft fans.

Ashes, dumped from the stokers at the rear of the boilers, drop through a chute which discharges into submerged ash pits located in the basement. Whiting traveling cranes equipped with 2 yd. grab buckets transfer the ashes from the pits into railroad cars alongside. This ash handling arrangement is well illustrated in Fig. 5.

Feed Water Is Softened and Deaerated

Feed water for the boilers, which is taken from the Drainage Canal, is treated by the Permutit Zeolite softening process and also by a sulphuric acid neutralizing system also furnished by the Permutit Co. For removing the

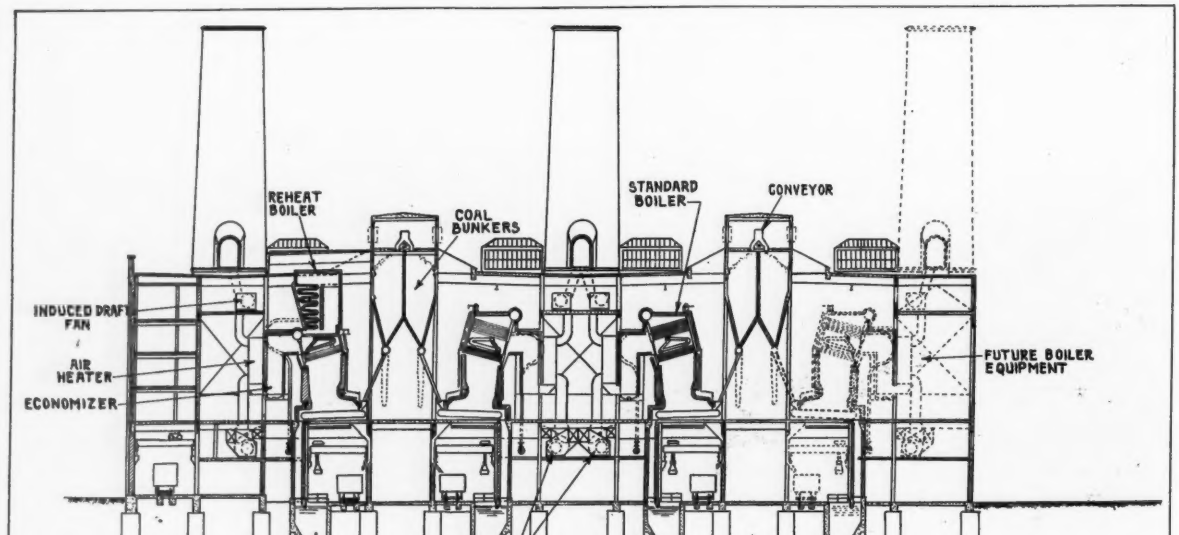


FIG. 5. CROSS SECTION THROUGH THE BOILER ROOM

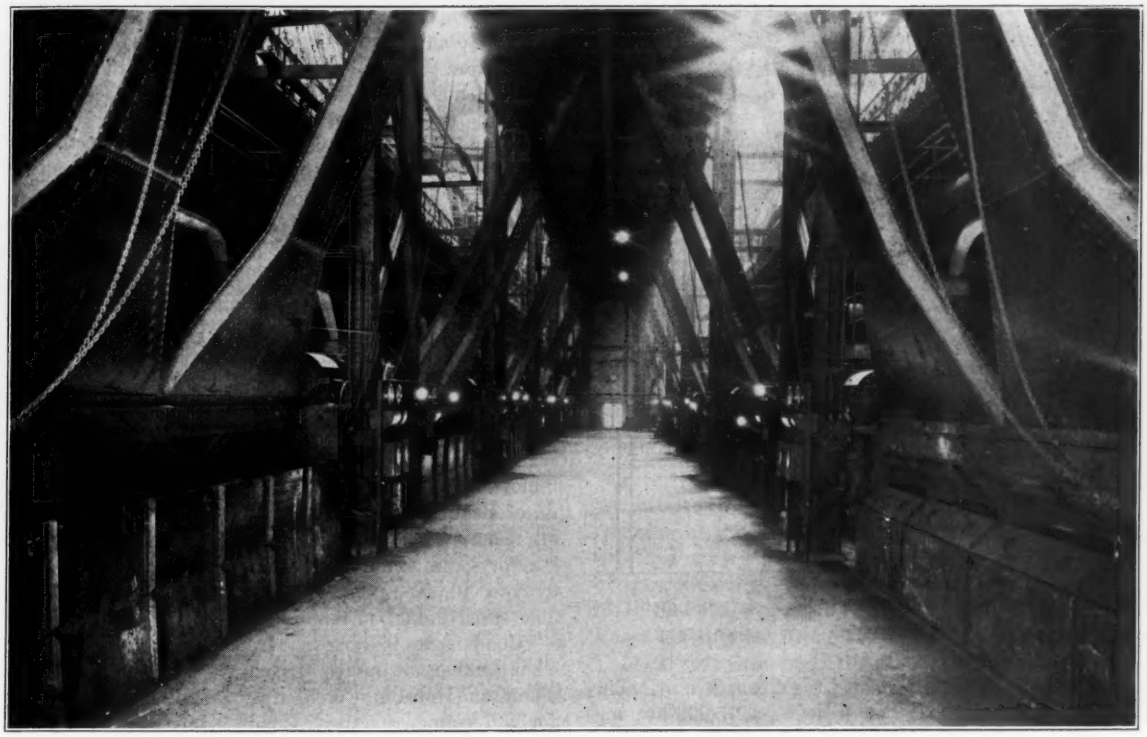


FIG. 6. ONE OF THE FIRING AISLES IN THE BOILER ROOM

oxygen content before delivery into the boiler an Elliott Co. deaerator with a capacity of 480,000 lb. of water per hr. is provided.

After its introduction into the system the make-up, together with the condensate, is picked up by the boiler feed pump and forced through high pressure economizers into the boilers. In the boilers the water level is controlled by Copes and S-C feed water regulators.

Three makes of boiler feed pumps are used, two Cameron pumps, three Bethlehem-Weir pumps, and two Weir pumps made in Scotland, the latter being installed in connection with the Parsons unit, although its service is not necessarily confined to that machine. The Cameron pumps are 4 stage units delivering 900 g. p. m. at a pressure of from 650 to 700 lb. per sq. in. and are driven by 600 hp., 2300 v., Westinghouse motors, at 3550 r. p. m. The Weir pumps are driven by 600 hp., 2300 v. British-Thomson Houston motors. Both the Westinghouse and British Thomson Houston motors are equipped with starting reactor. The Bethlehem Weir pumps are steam driven and are for emergency use only.

High Pressure Steam Valves Electrically Operated

All stop and check valves on the boilers are of the electrically operated type controlled from a central control panel in the boiler room. Those on the boilers for unit 1 have the Dean control and those on the boilers for units 2 and 3 have Chapman Valve Co. control. This panel also controls the 12 in. electrically operated valves in the cross ties between the main headers. With the exception of the stop and check valves, all other electrically operated valves are of Crane manufacture. The valves in the main boiler header are hand operated.

A 16 in. main stop valve is installed in the turbine headers immediately ahead of the steam separators. This is also electrically operated with three control stations, the main station at the valve, another at the turbine gage panel, and the third in the boiler room. These valves can be opened and closed only from the main station, the other two stations serving only for closing the valve.

Each turbine also has installed two valves, in the lines to and from the reheat boilers and one in the line bypassing the reheat boiler. All of these are electrically operated, the fromer being 30 in. valves and the latter 34 in. valves. These are controlled from the turbine gage panel.

The Turbine Room

If any one part of the Crawford Avenue Station is of greater interest both mechanically and architecturally than any other part of the station, unquestionably it is the turbine room. A general view of this wonderful room is shown in Fig. 2, but no picture can adequately convey an impression of its magnitude—it is so well proportioned. Three hundred and thirty-nine ft. in length, 125 ft. wide and with the ceiling some 80 ft. above the floor, this room is no doubt larger than anything else of its kind. The walls are faced with white tile from floor to ceiling. The floor is of red mosaic inlaid with yellow. All machinery is painted an olive green and hand rails are of polished brass. No piping is carried above the turbine room floor.

The present installation consists of three compound turbo-generator units, one a 50,000-kw. Parsons machine manufactured by C. A. Parsons and Co., Newcastle-on-Tyne, England, one a 60,000-kw. General Electric Co. unit, and the third a 50,000-kw. Westinghouse Electric and Manufacturing Co. unit. As may be noted from the plan, these three machines are installed side by side with their steam ends toward the boiler room. At the east

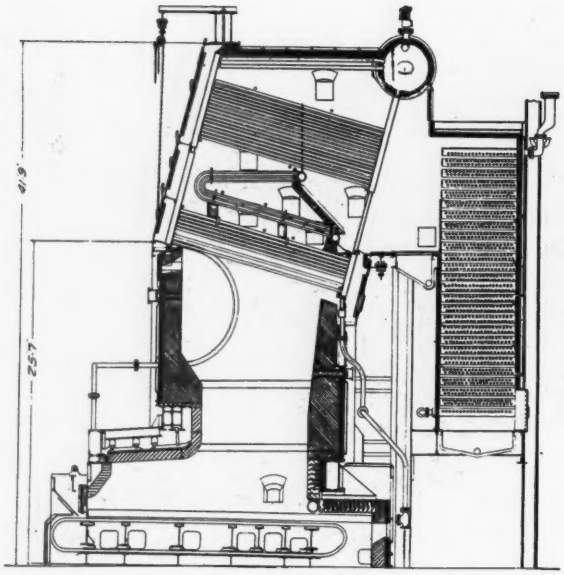


FIG. 7. SECTION THROUGH ONE OF THE BOILERS SHOWING LOCATION OF SUPERHEATER AND ECONOMIZER

end of the room space is provided for a fourth unit. This has already been ordered and is to be a 75,000-kw. machine.

Two motor operated traveling cranes with a span of 125 ft. between crane rails are provided for handling the various parts of the equipment in the turbine room. These are Whiting cranes, each with a capacity of 125 T. with an auxiliary hoist of 10-T. capacity for handling the smaller parts of the equipment.

Although the constructional features of these three machines are entirely different, the principles involved in their operation is the same. In each, steam at about 550 lb. gage is admitted to the high pressure element and after undergoing expansion in that element is returned to the boiler room to be reheated before passing it on to the low or intermediate pressure cylinders. All units provide for the extraction of steam at various pressures for feed water heating, and all are provided with vertical, two-pass surface condensers.

The generators are fitted with closed systems of ventilation for cooling the windings. The rotors of the generators on the General Electric and Westinghouse units are provided with fan blading which forces the cooling air through the windings. The Parsons generators on the other hand are not fitted with fan blading and external blowers are therefore provided.

Since each of the generating units is constructed along different lines, it will be best in describing them to consider each unit separately.

Mechanical Features of the Parsons Unit

The Parsons unit, located at the west end of the turbine room, consists of a high pressure turbine running at 1800 r.p.m., driving a generator of 15,500-kw. capacity an intermediate pressure unit operating also at 1800 r. p. m., driving a 28,500-kw. generator and a low pressure unit driving a 6000-kw. generator at 720 r.p.m. The generator rotors on this unit are all of the closed slot type, and are equipped with a device for indicating the temperature of the rotor windings while in operation. Each generator has its own direct connected exciter. The intermediate and low pressure turbines are arranged in tandem so that it looks like a single turbine with a generator at each end. The low pressure generator is located between the two halves of the vertical condenser.

The high pressure element is supplied with steam at 550 lb. gage and a total temperature of 750 deg. and exhausts at 115 lb. absolute and 430 deg. F. to the reheat boiler. Here the steam is reheated to 700 deg. and supplied to the intermediate turbine at 105 lb. absolute from which it exhausts to the low pressure at 2 lb. absolute.

Three extraction stages are provided for heating the feed water. These are located at 115 lb., 20 lb. and at 5 lb. The low pressure turbine exhausts into the two halves of a vertical 2 pass condenser and having 16,000 tubes and a total cooling surface of 56,000 sq. ft., 28,000 in each half. This condenser is provided with 6 jet type evactors made by G. & J. Weir, Ltd., each capable of removing 50 cu. ft. of free air per min., and using 1100 lb. of steam per hr. The heat in this steam is practically all reclaimed, however, as the exhaust is absorbed in the evactor steam condensers. Circulating water is provided by two 40,000-g.p.m. pumps driven by 350-hp. adjustable speed induction motors.

Condensate is removed from the condensers by two Weir condensate pumps, driven at 380 r. p. m. by British Thomson Houston Co. 53-hp., 2300-v. motors, arranged for full voltage starting. Condensate leaving the Parsons unit on its way to the economizers after three stage heating has a temperature of 315 deg. F.

The General Electric Machine

Of the three turbo-generators installed the General Electric unit is the simplest, at least insofar as general mechanical appearance is concerned. It is rated at 60,000 kw., 80 per cent power factor, and consists of a high pressure turbine direct connected to a 17,000-kw. generator, and a low pressure turbine direct connected to a 43,000-kw. generator. As was the case with the Parsons unit, steam from the high pressure cylinder is reheated to a temperature around 725 deg. before being delivered to the low pressure cylinder. The rating, temperature, and pressure of this unit are divided between the two machines as follows.

	High Pressure Side	Low Pressure Side
Rating, kw.	17,000	43,000
Speed	1,800	1,200
Initial pressure, 1 lb. abs.	550	110
Initial temp., deg. F.	725	725
Exhaust press., lb. abs.	120	0.5
Stages	10	14
Weight, lb.	196,000	716,000

In addition to the main generator, the high pressure turbine is direct connected to a 2000-kw. house generator. Exciting current for the entire unit is obtained from a direct current generator direct connected to the low pressure turbine.

Controlling mechanism on the high pressure turbine is similar to that on other large G. E. turbines. The main operating governor operates the main controlling valve through the agency of a pilot valve and a hydraulic cylinder. The medium used is oil under pressure and a lack of pressure at any time due to breakage of pipes or failure of pump will cause the steam valves to close,

shutting down the machine. The emergency governor is set to operate at a speed 10 per cent above normal. At this speed a small trip valve closes the main controlling valve by operating a pump cylinder; it also operates another trip valve, which closes the main throttle valve. The low pressure turbine has no throttle, but the steam coming from the reheater to the turbine flows through an intercepting valve, which, during normal operation, is held open by oil pressure in a cylinder. This valve is closed by the action of an operating governor on the low pressure turbine if the speed of this unit rises to 6 per cent above normal. If the speed drops, this valve is reopened. Steam flow control to compensate for changing loads is taken care of by the operating governor and controlling valve on the high pressure turbine, so that the intercepting valve has no partial opening position.

The emergency governor of the low pressure cylinder is connected to close the intercepting valve at 10 per cent above normal speed should the operating governor on the low pressure unit become inoperative.

For heating the feed water, the G. E. unit is also arranged for three stage extraction, taking steam at 33, 10.25 and 3.4 lb. absolute.

The condenser is built along the same general lines as that provided for the Parsons machine. It is a vertical, 2-pass surface condenser, built by the Worthington Pump and Machinery Corp., having 75,000 sq. ft. of cooling surface, arranged in two parts. The low pressure exhaust passes out through a double passage connection around the turbine shaft to the condenser which stands at the end of the turbine. These vertical condensers are somewhat of a novelty in steam power plant practice but are very well adapted to these large size turbines. With them it is possible to have an extremely effective connection between the turbine and condenser. They should have the advantage of giving a constant gravity head to the water, regardless of the amount of water passing through the tubes.

Condensate is removed by two Worthington centrifugal pumps, one driven at 870 r.p.m. by 100-hp., 2300-v., Westinghouse motors, arranged for full voltage starting; the other, turbine driven. The remaining auxiliaries operated in conjunction with the G. E. unit are listed as follows: 4 hydraulic jet pumps, 2 hydraulic supply pumps, 1 steam jet evactor and a condensate drain pump. Cooling water is circulated through the condenser by two 40,000-g.p.m., 36-in., Worthington pumps direct connected to 350-hp., 2300-v., slip-ring, induction motors. These pumps operate normally at 345 r.p.m.

Details of the Westinghouse Unit

Like the Parsons unit, the Westinghouse unit is a three cylinder machine, but the arrangement is quite different. In this machine, which is rated at 50,000-kw., 80-per cent power factor, the high and intermediate pressure cylinders are arranged as a tandem compound unit, driving a generator of 30,000-kw. capacity and a 2000-kw. house turbine. The low pressure turbine, which is placed alongside of the high and intermediate pressure element, is direct connected to a 20,000-kw. generator. The exciter for the entire machine is also driven by the low pressure element. Both generators operate at 1800 r. p. m.

At full load the high pressure cylinder expands the steam which enters at 550 lb. gage and 725 deg. to 132 lb. absolute. The steam is then reheated and returned to the intermediate pressure cylinder at 122 lb. abs. and 700 deg., where it is expanded to 16.5 lb. absolute, passing to the low pressure element.

The arrangement of the high and intermediate pressure turbines is such that the steam flow is opposed so that one may neutralize the thrust of the other, eliminating the necessity for large dummies or balance pistons. The low pressure element is of the double flow type, the steam entering at the center of the rotor and flowing both ways into the 65,000-sq. ft. vertical condenser which practically surrounds the turbine. Reaction blading is used throughout and the last two rows of blades have a divided exhaust arrangement, a scheme for reducing the length of the low pressure blades, originally developed by K. Baumann of Manchester, England.

Since the condenser is vertical, the condensate must pass over the cold tube plate with the objectionable feature that the condensate temperature is depressed. To restore this, it is reheated in a hotwell in the form of a jet condenser receiving steam direct from the exhaust chamber of the turbine. The hotwell or jet condenser is provided with vapor connections to a low pressure zone of the condenser.

Three stage extraction heaters are provided for feed water heating, taking steam at 50, 17 and 4 lb. absolute.

Auxiliary equipment for this unit consists of one Westinghouse Leblanc hydraulic vacuum pump, one Westinghouse steam jet evactor, two Westinghouse condensate pumps and one emergency condensate pump, each driven by 100-hp., 2300-v. Westinghouse motors, and two 35,000-

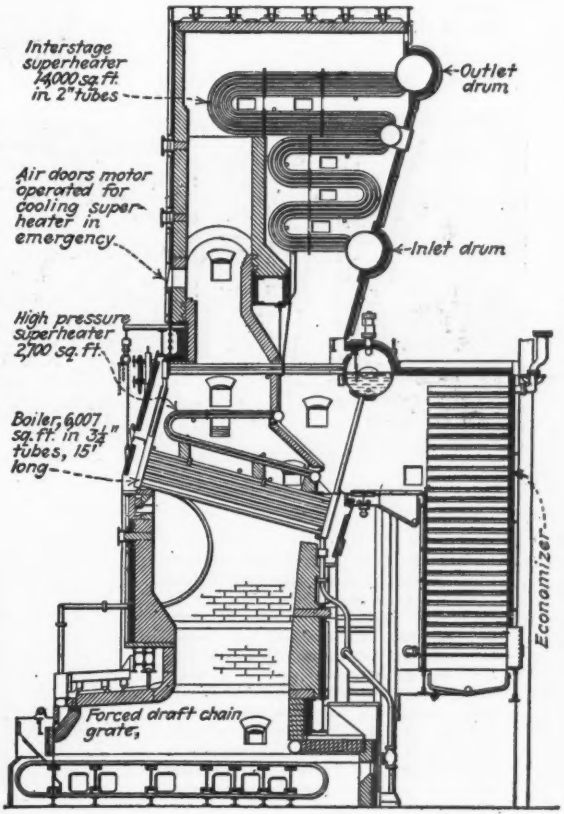

Interstage superheater 14,000 sq. ft. in 2" tubes
Outlet drum
Air doors motor operated for cooling superheater in emergency
Inlet drum
High pressure superheater 2,700 sq. ft.
Boiler, 6,007 sq. ft. in 3½" tubes, 15' long
Economizer
Forced draft chain grate

FIG. 8. AFTER PASSING THROUGH THE HIGH PRESSURE TURBINES, THE STEAM IS REHEATED IN THIS TYPE OF BOILER

Points of Interest at Crawford

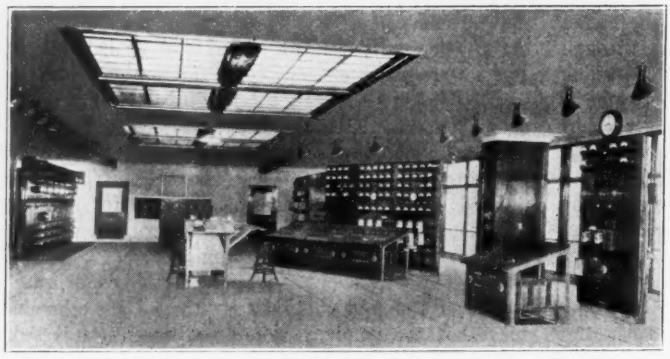
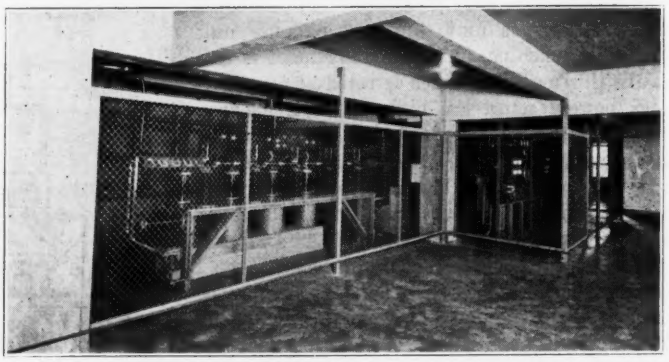


Fig. 9. The Operating Gallery. This is the brain center of the station from which the operation of all electrical equipment is controlled. This room is located on the fourth floor of the switchhouse, overlooking the turbine room. The bench board controlling the three main generating units is shown near the center of the room. On the vertical panel back of it are mounted the indicating and recording instruments for the machines. The long vertical switchboard on the left is the line control board.

Fig. 10. A view of the crib house showing the intake flume in the foreground. All water for condensing purposes is drawn from the Sanitary District Canal, through this flume and into the crib house where are located the traveling water screens. From the crib house the water passes through an intake tunnel 12 feet square to the turbine room. The water is discharged through a return tunnel 18 feet high by 16 feet wide. The bottoms of all tunnels are 33 feet below the ground line.

Fig. 11. This shows the oil circuit breaker mechanisms on the third floor of the switchhouse. The mechanism is spring operated, the spring being compressed by oil under a pressure of about 450 lb. per sq. in. In operating this type of switch, the charging switch button is first pulled. This starts the hydraulic pump, opens a solenoid operated valve on the mechanism and when the springs are fully compressed the pump is shut down by a pressure governor. A signal is also flashed in the control room.

Fig. 12. For testing the insulation of cables and other electrical equipment, a Kenotron test set is provided. This is shown in this photograph. It consists of transformers for stepping low voltage alternating current up to a high value and four Kenotron tubes for converting the high voltage alternating current to direct current. With this set, direct currents as high as 200,000 v. can be obtained between positive and negative terminals.



g.p.m. circulating pumps driven by 300-hp., 250-r.p.m., Westinghouse slip-ring motors.

Electrical Features

The electrical system in the switchhouse at Crawford follows closely the plan used at Calumet station and is built upon the isolated phase system. In this type of construction, the three phases of the circuit are carried on separate walls spaced 21 ft. between centers, with barrier walls between the phases to prevent the spread of possible trouble from one phase to another. The wide separation of busses and associated equipment reduces the possibility of phase to phase short circuits to a minimum, while the current in any breakdown of a phase to ground is limited by resistances in the neutral connections of the generators.

The generators feed into either of the two main busses through either of two oil circuit breakers, as shown on the single line diagram of the electrical system in Fig. 17.

The 33,000-v. tie lines to other generating stations are each connected through 33,000/12,000-v. transformers to one of the main busses. The 12,000-v. feeder circuits are grouped on feeder busses which are so arranged that they may be connected to either of the main busses.

The two sections of the main bus are normally operated in parallel, but in the event of trouble on either section of the system, the two sections are automatically cut apart, thus isolating the defective section.

As shown in Fig. 14, the switchhouse is a four story building with offices on the top floor. The oil switch

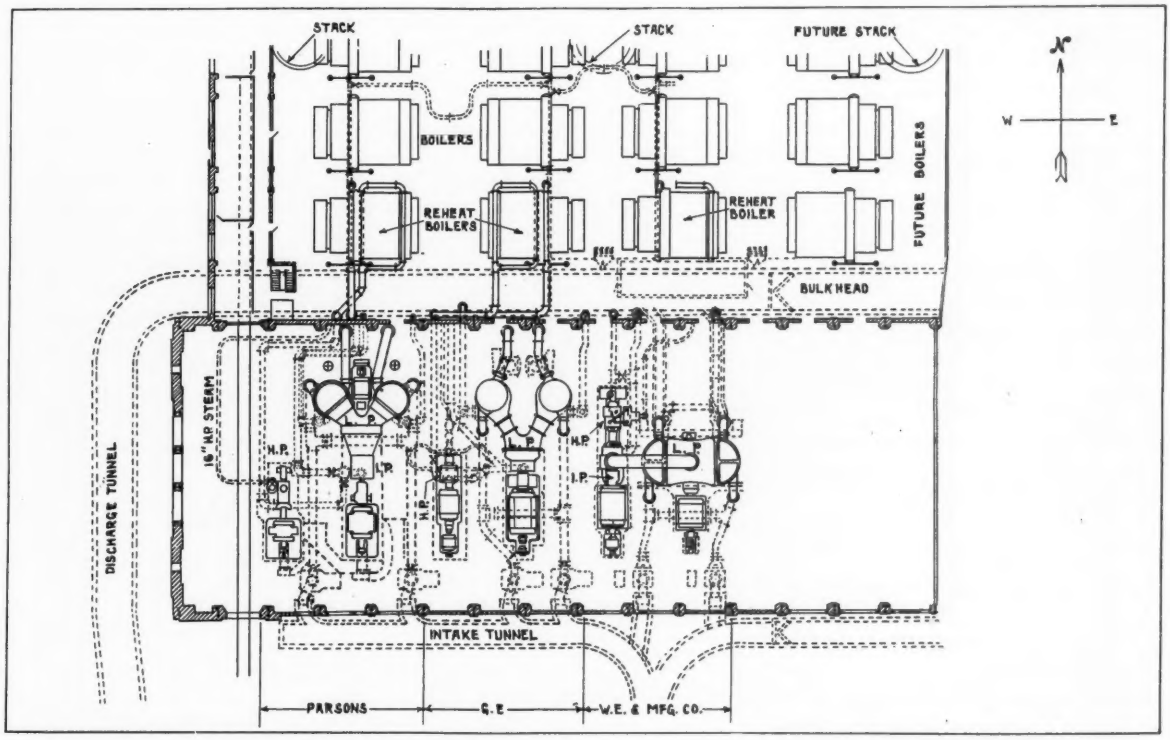


FIG. 13. PLAN SHOWING ARRANGEMENT OF GENERATING UNITS IN THE TURBINE ROOM

Each of the two or three generators constituting one generating unit are permanently connected in parallel to form a single unit and the combination connected to the main busses through a reactor.

The permanent parallel connection of the two or three generators on each turbine unit and the nature of turbines themselves introduce an interesting feature in the method of starting up the machines. It is evident that the low pressure turbines will not start to rotate until the high pressure units are carrying sufficient load to supply this steam. In starting, therefore, the fields of all generators of the unit are excited from a separate source of excitation, allowing the low and intermediate pressure generator to operate as synchronous motors from current supplied by the generator on the high pressure shaft. All three generators, therefore, come up to speed at once and when sufficient steam enters the lower pressure turbines to enable them to carry load, the generators cease their motor action and take over the load. The excitation is then thrown over to the shaft driven exciter.

mechanism is installed on the third floor, the oil wells or switches on the second, and the reactors on the first floor. All cables enter in the basement. The reactor and oil well floors are fitted with an extensive duct system and exhaust fans which will quickly clear these floors of smoke in case of a short circuit or fire. The windows on these floors are controlled by thermostats, which open them when the temperature rises.

Generator leads come in along the basement ceiling and at each phase pass upward to their respective reactors and circuit breakers. All three conductor feeder cables enter the station below the basement floor and are belled up under B phase. Here the conductors separate and the A and C phases are carried in conduit to the A and C phase walls. Each of the three conductors is connected to a disconnective switch below reactor and up through the oil switches to the line busses in the upper part of the oil switch room.

Principal Equipment at Crawford Avenue Station

Present Building

Capacity, 235,000 kw.

Boiler room,	Length 331 ft.	width, 237 ft.
Turbine room	Length 340 ft.	width, 126 ft.
Switch house,	Length 206 ft.	width, 74 ft.
Transformer house	Length 291 ft.	width, 41 ft.

Ground area per kilowatt, total.....0.63 sq. ft.
Volume per kilowatt, net.....54.8 cu. ft.

Boilers, Superheaters and Economizers

Make.....Babcock and Wilcox Co.
Types of boilers, Steel cased, cross-drum, water tube.
Number installed.....12
Water heating surface, each.....16,615 sq. ft.
Superheating surface, each.....2,700 sq. ft.
Economizer surface, each.....11,054 sq. ft.
Diameter of tubes, lower deck, 3¼ in. upper deck, 2 in.
Length of tubes.....15 ft.
Lower deck, 8 tubes high, 40 sections wide.
Upper deck, 17 tubes high, 40 sections wide.
Boiler surface installed, per kilowatt, 1.35 sq. ft.
Ratio superheater surface to boiler surface, 1 to 6.15.
Ratio economizer surface to boiler surface, 1 to 1.495.
Boiler pressure, 600 lb. gage. Steam temperature 750 deg. F.
Soot blowers, Diamond, 20 units per boiler.
Air Heaters.....2 B. & W. Co., 3 Buffalo Forge Co.
Type.....Tubular
Surface each, approximate.....10,000 sq. ft.

Reheat Boilers

Make.....Babcock and Wilcox Co.
Water heating surface, units 1 & 3, 6007 sq. ft., unit 2, 5509 sq. ft.
Superheating surface.....1700 sq. ft.
Reheating surface.....14,000 sq. ft.

Furnaces

Boiler setting, Brick, steel encased by Bishop Contracting Co.
Suspended arches.....10 Liptak, 5 Detrick
Insulating brick.....Nonpareil
Furnace volume—Unit No. 1, 6200 cu. ft.
Furnace volume—Units No. 2 and 3, 5910 cu. ft.
Furnace volume—Per 10 sq. ft. of boiler surface. Unit No. 1 3.73 cu. ft. Units 2 and 3 3.56 cu. ft.

Stokers and Draft Apparatus

No. per boiler, One type.....Forced draft, chain grates
Width.....24 ft.
Make, 5 B. & W. Co., ...effective area 444 sq. ft.
5 Coxe .....effective area 423 sq. ft.
5 Illinois .....effective area 423 sq. ft.
Drive—5 hp. 230 v. D.C. Westinghouse Elec. & Mfg. Co. motors. 2 per stoker.
Forced draft fans.....30 Buffalo Forge Co.
Capacity each.....40,000 c.f.m.
Drive.....25 hp. var. speed 2300 v. Westinghouse motors
Aux. F. D. Fans.....30 B. F. Sturtevant Co.
Capacity each.....5500 c.f.m.
Drive.....440 v. G. E. motors
Induced Draft Fans.....10 B. F. Sturtevant Co.
Induced Draft Fans.....5 Green Fuel Economizer Co.
Capacity each.....115,000 c.f.m
Drive.....150 hp. 2300 v. Westinghouse motors
Stoker damper control.....The Hagan Corp.
Stacks Diam.....One 26 ft., One 30 ft.
Height above boiler room floor.....150 ft.
Type.....Steel, brick lined

Coal Handling

Car dumper.....Wellman-Seaver-Morgan
Capacity.....20-120 Ton Cars per hour
Drive.....50 hp. 440 v. G. E. motor
Breakers.....2 Bradford capacity each 25 T./Hr.
Drive.....150 hp. 440 v. Westinghouse motors
Coal carried either to storage or bunkers by 36 in. belt. Capacity either way 400 Tons per hr.
Coal stored by traveling stacker and reclaimed by traveling tower with grab bucket.
Entire equipment furnished by The Koppers Co.
Storage capacity present 99,000 T. ult. 340,000 T.
Track scale by Fairbanks Morse & Co.
Car puller, Whiting Corp.

Miscellaneous

Safety valves.....Manning, Maxwell & Moore Inc.
Ornamental iron wk.....G. A. Fuller Co.
Structural steel.....American Bridge Co.
Form work.....The B & A. Co.
12 Traveling Screens.....Link Belt Co.
Screw drive.....5 hp. 440 v. Westinghouse Motors
30 coal valves and spouts.....Henry Pratt & Co.
Smoke flues.....Henry Pratt & Co.
Fan ducts.....The Sykes Co.
15 4-in. Meroon F.W. Regulators.....D. H. Skeen & Co.
10 4-in. S-C F.W. Regulators.....The S-C Regulator Co.
5 4-in. Copes Spec. F.W. Regulators.The Northern Equipt. Co.
Metering Equipment.....The Bailey Meter Co.
2 Tubular Air Coolers.....The Westinghouse Mfg. Co.
2 Strainer Units.....E. B. Badger & Sons Co.
2 125 T. Whiting traveling cranes.

Turbo Generators

	Unit No. 1	Unit No. 2	Unit No. 3
Make	Parsons	Gen. Elec.	Westinghouse
Cap. high press. sec.	15,500 kw.	17,000 kw.	30,000 kw.
Cap. int. press. sec.	28,500 kw.	.....	.....
Cap. low press. sec.	6000 kw.	43,000 kw.	20,000 kw.
Steam press., throttle	550 lbs. G.	550 lbs. G.	550 lbs. G.
Steam temp., throttle	725°F.	725°F.	725°F.
Steam press., reheat	115 lbs.Abs.	120lbs.Abs.	132½lbs.Abs.
Steamtemp.beforereheat	430°F.	412°F.	.....
Steam temp. after reheat	700°F.	725°F.	700°F.
Exhaust press.	1 in. Hg Abs.	1 in.	1 in.
Speed hp. section	1800 r.p.m.	1800 r.p.m.	1800 r.p.m.
Speed I.P. section	1800 r.p.m.		
Speed L.P. section	720 r.p.m.	1200 r.p.m.	1800 r.p.m.
Gen. air cooler	Surface	Fin. surface	Surface
House gen.		2000 kw.	2000 kw.

Condensers

Make	Parsons	Worthington	Westinghouse
Type	Vert. Surface	Vert. Surface	Vert. Surface
Surface total	56,000 sq. ft.	75,000 sq. ft.	65,000 sq. ft.
Surface per kw.	1.12	125	1.30
Tube active length	19 ft.	19 ft.	19 ft.
Tubes make	British American Metals Co.		

Circulating Pumps

Make	Worthington	Worthington	Westinghouse
No.	2	2	2
Drive	Motor	Motor	Motor
Cap. each	40,000 g.p.m.	40,000 g.p.m.	35,000 g.p.m.
Cap. per kw.	1.60 g.p.m.	1.33 g.p.m.	1.40

Condensate Pumps

Make	G. & J. Weir	Worthington	Westinghouse
No.	2	2	3
Cap. each	1000 g.p.m.	1200 g.p.m.	950 g.p.m.
Drive	Motor	1 motor, 1 turbine	Motor
Booster Pumps	2		
Make	G. & J. Weir		

Capacity each—450,000 lbs. per hr. from 25 lbs. to 200 lbs.
Drive Steam turbine

Air Pumps

Type	Steam ejectors	1 LeBlanc Air
No.	2 sets	Hydraulic Vac. Pump
	Four	1 Banks steam jets
	4-2 stage steam jets	

Boiler Feed Pumps

Make	G. & J. Weir	A. S. Cameron	A. S. Cameron
No.	2	One	One
Stages	One	Four	Four
Cap.	500,000 lbs. per hr. against 700 lbs.	800 g.p.m. against675lbs.	900 g.p.m. against675lbs.
Speed	3540 r.p.m.	3450 r.p.m.	3450 r.p.m.
Drive	Motor	Motor	Motor
Make	Bethlehem Shipbuilding Corp.	Bethlehem Shipbuilding Corp.	
No.	One	One	One
Stages	One	One	One
Cap.	900 g.p.m. against 675 lbs.	900 g.p.m. against675lbs.	900 g.p.m. against675lbs.
Drive	Steam turbines	Steam turb.	Steam turb.
F. W. Heaters	Bethlehem	The Elliott Co.	The Elliott Co.
No.	6 heaters closed	Deaerator & F. W. Heaters	Deaerator & F. W. Heaters

Valves and Piping

High pressure piping furnished by Crane Co. Erected by Wm. A. Pope.
2-12 in. automatic relief valves.....D. H. Skeen & Co.
Atmospheric relief valves.....Edwards Valve & Mfg. Co.
Steam separators .....M. W. Kellogg Co.
Circulating water piping.....M. W. Kellogg Co.
Pipe covering and insulation.....Johns-Manville, Inc.
6 mot. op. sluice gate valves....The Ludlow Valve Mfg. Co.
Globe Valves.....Edward Valve & Mfg. Co.
10 non-return valves equipped with Chapman Motor Control and 5 non-return valves equipped with Payne-Dean Motor control.
Stop and check valves.....Edwards Valve & Mfg. Co.
Blow-off valves.....Edwards Valve & Mfg. Co.
Gate valves .....Crane Co.
Safety valves .....Manning-Maxwell & Moore
Steam traps.....Crane Co. and The C. E. Squires Co.

Electrical Equipment

Switchhouse Oil Circuit Breakers:
Make.....General Electric Co.
Type.....FHD—17 Isolated Phase, Hydraulic
Capacity.....Generator and bus section, 4000 amp. Feeders, 600 amp. Line bus, 2000 amp. Transformer, 1000 amp.
33,000 and 22,000 V. Transmission Oil Circuit Breakers:
Make.....Westinghouse Elec. & Mfg. Co.
Type.....G-221 out door
Capacity .....600 amp.
Station Auxiliary Power Breakers:
Make .....Condit Elec. Mfg. Co.
Type.....F-11 and D-17
Transmission Transformers, 4 G. E., 1 Westinghouse.
Capacity .....600 amp.
Auxiliary Power Transformers:
Make.....2—2300 v., 4000 kv.a., Pittsburgh; 2—440 v., 2000 kv.a., Pittsburgh; 2—115 v., 200 k.va., Pittsburgh; 1—2300 v., 2500 kv.a., Westinghouse

All out-going lines from this station are installed in an extensive underground system. Lead and paper insulated cables are drawn into stone ducts laid with a separation of concrete to produce a fire protection between adjacent cables. The various conduit lines on the property have been laid out for the ultimate capacity of the station, and in such a manner as to allow an extreme flexibility in routing of cables. Seven independent conduit trunk lines radiate from the station, two south-going through a tunnel under the Sanitary District Canal, and five north-going. Additional conduit trunk lines will be provided from the station, as future development may require. Thirty outgoing lines are at present installed with provision in the station conduit system for ninety additional lines.

Hydraulically Operated Oil Switches Used

The oil circuit breakers used are the General Electric Co. hydraulically operated type F H D—17, the generator and bus section switches having ratings of 4000 amp., the group switches 2000 amp., and the line switches, 600 amp. They are equipped with disconnecting switches which may be operated automatically by the switch mechanism or operated manually from the mechanism floor. The mechanism is spring operated, the spring being compressed by oil under a pressure of about 450 lb. per sq. in. furnished by either of two gear pumps driven by 20 hp. electric motors, one a 440 v. a.c. motor and the other a 230 v. d.c. motor. Normally the one driven by the a.c. motor is used.

In operating this type of oil switch, the charging switch button is first pulled. This starts the hydraulic pump and opens a solenoid operated valve on the mechanism and when the spring is carefully compressed the pump is shut down by a pressure governor and a signal lamp on the control board lights up, notifying the operator that the closing button may be pulled.

An interesting feature in connection with the oil wells is that they are all of 600 amp. capacity. The difference in capacity for different lines is obtained by the use of external

FIG. 15. VIEW ON THE SECOND FLOOR OF THE SWITCHHOUSE SHOWING THE OIL CIRCUIT BREAKERS

shunts which, when the switch is closed, short circuit the oil well. These shunts are arranged to close immediately after the closure of the oil switch contacts and to open an instant before the oil switch contacts open. The submerged contacts only carry full current during the instant of opening or closing. This arrangement is highly satisfactory, as it enables any of the oil wells to be interchanged and necessitates the carrying of only one size of spares.

Control of the electrical system is effected from the main operating gallery on the top floor of the transformer house. A view of this room is shown in Fig. 9. The benchboard is shown near the center of this room. On this are mounted all the switches and indicating lamps for controlling the operation of the oil switches, rheostats, and governors of the turbo-generators. On the panel back of the benchboard are mounted the indicating instruments

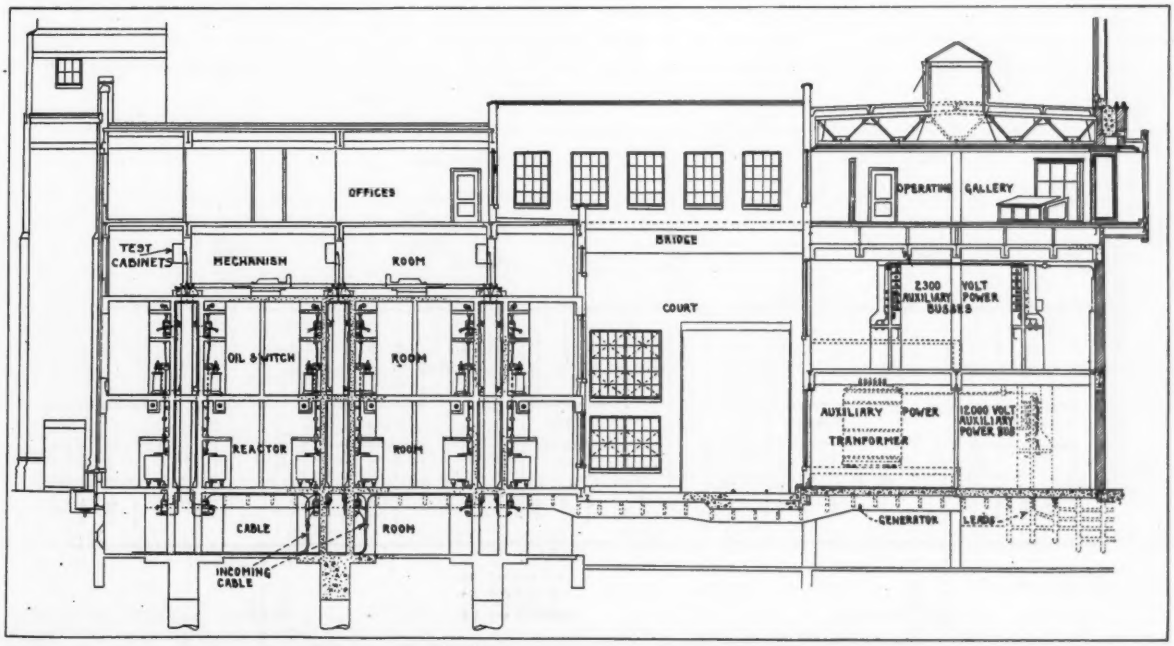


FIG. 14. SECTION THROUGH THE SWITCHHOUSE SHOWING ISOLATED PHASE ARRANGEMENT

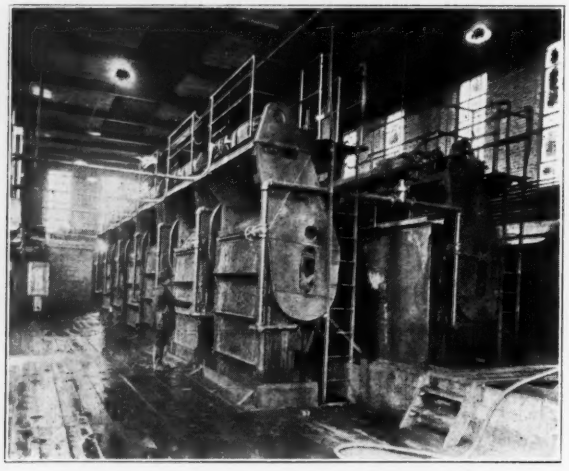


FIG. 16. CIRCULATING WATER INTAKE SCREENS IN THE CRIB HOUSE

necessary to show the load carried by the machines and also the graphic recorders.

The long vertical board at the left of the room is the line control board carrying the control mechanism for the oil switches on the outgoing transmission lines.

All current is generated at 12,000 v., 3 phase, 60 cycles. Excitation is normally obtained from the direct connected exciters on the generator units, but throw over switches are provided for supplying excitation from the storage battery while starting up, or in case of emergency. Field current control for main generators, exciters and house generators is by motor operated rheostats installed on panels erected in alcoves on the south wall of the turbine room. These rheostats are controlled from the operating gallery.

The generators and connections, up to the reactors, are protected by balanced relays which, in case of excessive unbalance, trip and cause all generator switches on that unit to open. In addition, all field switches and neutral switches are also opened, the auxiliaries are disconnected from the house generator and connected to the station transformer bus, and a signal is operated in the control room.

To limit the fault current in case of an accidental ground, three ohm resistors are connected in series with the generator neutral circuit.

Emergency Lighting System Provided

Station lighting is obtained normally from a 3 phase, 4 wire, system 208 v. between phases, 120 v. to neutral. The lamps are connected between any one phase and the neutral. Emergency lighting circuits are provided which are automatically thrown over to the storage battery when the normal lighting voltage falls.

Direct current for reserve excitation, emergency lighting and the stoker motors is furnished by two motor generator sets. These are installed in the transformer house and are Westinghouse units consisting of a 200 kw., 800 amp., 250 v., d.c. generator, direct connected to a 290 hp., 2300 v., a.c. motor, arranged for full voltage starting. One of these sets is sufficient to carry the entire load, and, under normal operation, floats on the main storage battery circuit.

Two storage batteries are installed, one a large 120 cell, 2000 amp. hr., 55 plate battery for reserve excitation, emergency lighting, and other a small battery for supplying the control circuits.

Insulation Tested by High Voltage Direct Current

For testing the insulation of cables and other electrical equipment, a Kenotron test set is provided. This consists of a transformer for stepping low voltage alternating current up to a high value and four Kenotron tubes for rectifying this high voltage alternating current. With this set direct currents as high as 200,000 v. can be obtained, between positive and negative terminals.

On the oil switch mechanism floor are installed the test cabinets by means of which the transmission lines may be grounded or connected to test cables from the Kenotron set.

Crawford Avenue station was designed by Sargent and Lundy, of Chicago, in co-operation with the engineers of the Commonwealth Edison Co. The electrical features were designed entirely by the engineering department of the Commonwealth Edison Co. and constructed under its direction by the company's construction department. The architects of the building were Graham, Anderson, Probst and White of Chicago.

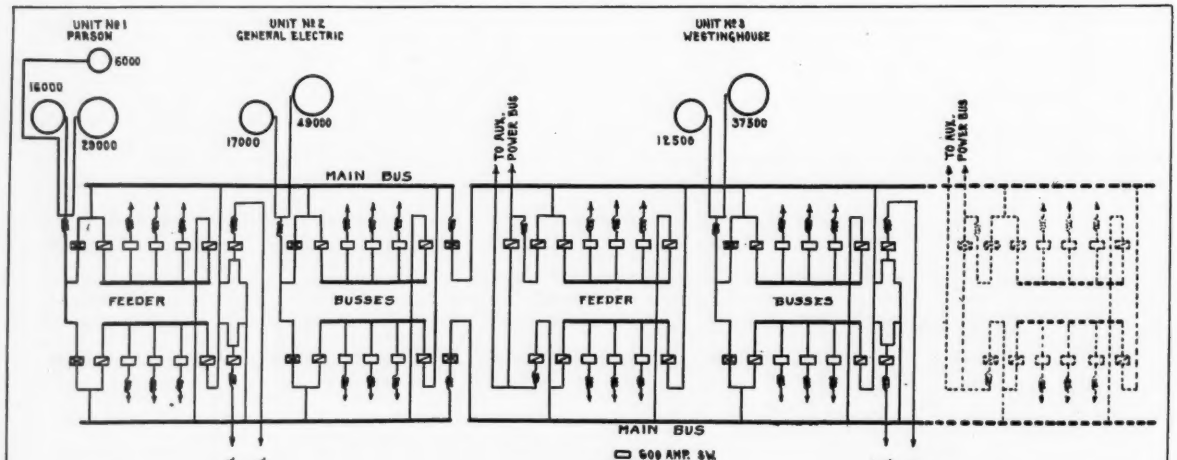


FIG. 17. SINGLE LINE DIAGRAM OF THE BUS SYSTEM

New Furnace Design Permits Burning Heavy Oil

LARGE COMBUSTION SPACE AND INSIDE MIXING TYPE OF BURNERS PREVENT DEPOSITION OF CARBON AND IMPROVE OPERATION

BURNING GAS OIL, or high grade marketable fuel oil does not require as careful choice of suitable equipment and furnace design as when using heavy, dirty oils, which cannot be sold in the open market. Many plants now burning expensive grades of oil could effect material saving by redesigning their equipment to permit burning low grade oil which is ordinarily unsalable.

One plant had been burning light oil with a fair degree of success but the cost of producing steam was excessive. A large amount of heavy oil (12 to 14 deg. Be.) was available and the management decided to cut expenses by burning this oil. The mere fact that it was heavy was not the main deterrent since heating reduced the viscosity enough to make it flow freely. But the main objection to its use was the large amount of free carbon held in suspension until heated, when it would drop out at bends or points in the line where the velocity was reduced. This sludge soon clogged up small openings in the burners and necessitated changing the burners so often that boiler output was seriously handicapped.

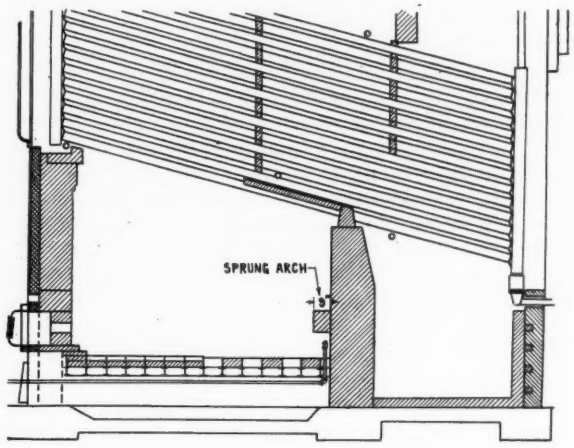


FIG. 1. ORIGINAL SETTING WITH UNUSED SPACE AT THE REAR

In Fig. 1 is shown a side elevation of the original furnace. The floor was suspended on I-beams with the rear end of open checker-work. The burner was of the outside mixing type. Oil was forced out of the upper slot in an almost horizontal plane, while the steam from the lower slot was forced upward on an angle, striking and mixing with the oil spray in air just in front of the nozzle and producing a short flat flame. The line leading to the burner is shown in the drawing just underneath the checkered floor. It was about 10 ft. long and consisted of a ¼-in. oil line inside of a 1-in. steam line.

There were 3 burners to each 600 hp. boiler, which were set on 4 ft. 4½ in. centers. Each burner had a small arch built over it and which extended forward from the bridge wall about 9 in. This was not so much for the purpose of effecting ignition as to prevent air from going straight up along the bridge wall. These arches, however, were inadequate for proper mixing of air and gases.

Due to the free carbon, burner tips were continually filling with coke, fires going out and, besides with 3 burners, the boilers could not be operated at much more than 150 per cent of rating consistently.

To overcome all of these difficulties it was decided to remodel the furnace and install efficient burners of the inside mixing type. In the original setting there was considerable dead space back of the bridge wall, which,

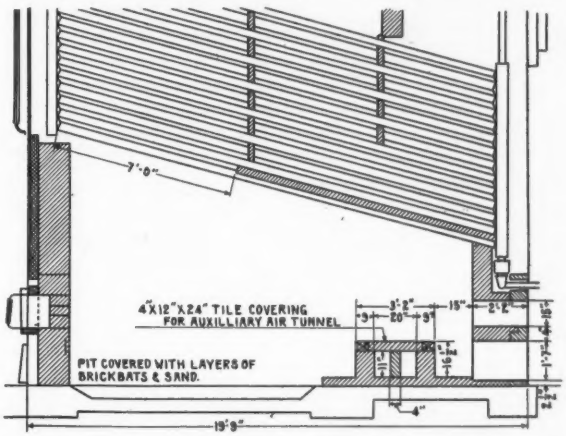


FIG. 2. MODIFIED FURNACE DESIGN SHOWING AIR PORTS AND BURNER OPENINGS THROUGH REAR WALL

if utilized, would materially increase the combustion space. How this was done is shown graphically in Fig. 2. The checkered floor and bridge wall were torn out and the short horizontal baffle originally extending from the bottom of the front vertical baffle to the top of the bridge wall, was extended to the rear wall. The thick-

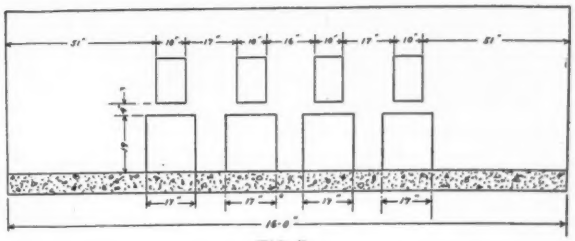


FIG. 3

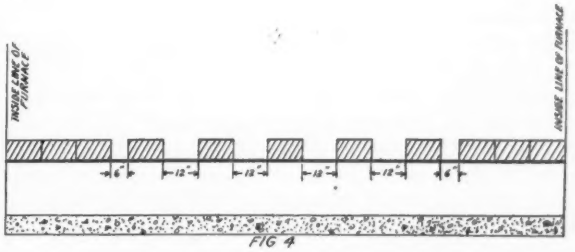


FIG 4

FIG. 3. DETAILS OF BURNER OPENINGS AND AIR PORTS IN REAR WALL

FIG. 4. FRONT ELEVATION OF AUXILIARY AIR TUNNEL SHOWING TILE ON TOP

ness of the latter was increased to 26 in. to protect the mud drum and blow off lines.

Details of burner openings and air ports are shown in Fig. 3. In Fig. 2 there is also shown an auxiliary air tunnel which extends across the width of the furnace with openings on each side. This tunnel is covered over with 4 by 12 by 24 in. tile, spaced so as to permit air openings directly below the flame of each burner. Sliding

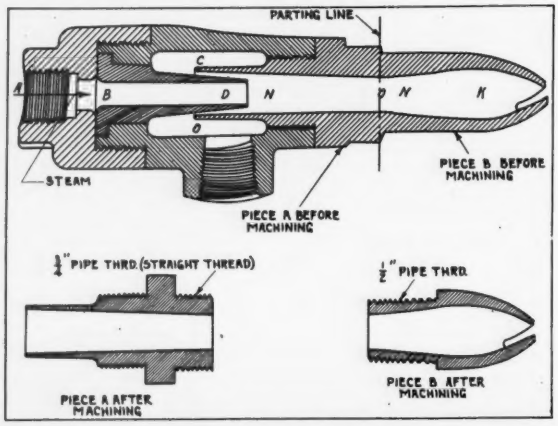


FIG. 5. DETAILS OF INSIDE MIXING TYPE BURNER

FIG. 7. METHOD OF EXTENDING NOZZLE TIP

metal doors, on each side of the furnace at the tunnel openings, were provided for closing off this auxiliary air when operating with light loads. A front elevation of this auxiliary air tunnel with arrangement of tile for air openings is shown in Fig. 4.

About twice the combustion space of the original setting is provided by the furnace design shown in Fig. 2 which also permitted a long gas travel, insuring good mixing of air and combustible gases before entering the tube bank. No difficulty at all was found in operating the boiler at 200 to 250 per cent of rating with no appreciable damage to brick work.

In order to derive full benefit from the new setting it was realized that efficient burners must be used. Several designs of the inside mixing type were tried out and finally the one shown in Fig. 5 was selected. Subsequent tests proved the wisdom of this choice. Steam is introduced at *A*, blown through nozzle *BD* at high velocity, which causes a partial vacuum at *C* and *E*. Oil is introduced at *F* and this vacuum permits freedom of flow around the outside of the steam nozzle. Steam and oil form contact at *N*, and by the time *K* is reached the oil is well atomized. These burners were placed through the burner openings in the rear wall with the end of the nozzle even with the inside edge of the opening. Steam and oil lines were then run out to their respective manifolds as shown by the installation in the foreground of Fig. 6. The brick wall built up around the blown-down pipes was for the purpose of protecting the operator from the intense radiant heat of the burners.

At first this method of installing the burners seemed quite satisfactory and unusually good results were obtained. But later on when an exceptionally poor grade

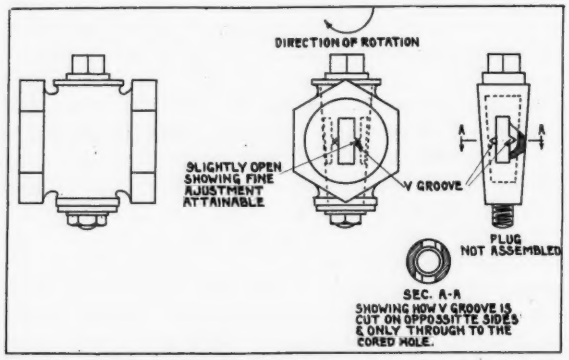

DIRECTION OF ROTATION
SLIGHTLY OPEN SHOWING FINE AJUSTMENT ATTAINABLE
V GROOVE
A
A
PLUG NOT ASSEMBLED
SEC. A-A
SHOWING HOW V GROOVE IS CUT ON OPPOSITE SIDES & ONLY THROUGH TO THE CORED HOLE.

FIG. 8. FINE CONTROL OF OIL FLOW BY MEANS OF V-NOTCHES IN STEAM COCK

of oil was used it was found that free carbon began to be deposited in the bend in the line just before oil entered the burner at *F*. Coking started at this point and in some cases the radiant heat caused it to extend back almost to the oil line manifold. In order to overcome this difficulty an original scheme was hit upon. Nozzle tip *NK* was cut in two at *O* and each of the ends so formed provided with pipe threads so that the two halves could be joined together by any length of pipe desired. The end of the inner half of the nozzle was provided with threads for ¾-in. pipe, while the other half was threaded for ½-in. pipe. These halves were then joined as shown in Fig. 7. With the installation of these modified burners, oil and steam were mixed behind the brick wall, away from the radiant heat, therefore there was no chance for coking in the line. In addition, this long extended nozzle gave a better chance for atomization, used less steam, and made less noise than before.

Method of Controlling Oil Feed Important

One of the most important items in efficient oil firing is fine adjustment of the oil feed. With the original burners shown in Fig. 1, the oil feed was controlled by needle valves which were distinctly unsatisfactory on account of clogging of the needle hole and sediment adhering to the needle. To eliminate this difficulty the needle valves were discarded and standard steam cocks used. Fine adjustment of oil flow was effected by cutting V-notches in the core and body of the cock as shown in Fig. 8. A flat piece of strap iron with a square hole cut in one end to fit over the head of the core was used for a handle. These are shown in Fig. 6.

With the new burners and furnace design results were even better than had been expected. With more efficient combustion and lowering of flue gas temperatures there was an average increase of 7 per cent in efficiency, 75 to 100 per cent more load could be carried with good results and there was much more flexibility of control. Maintenance costs for furnaces and burners were materially decreased.

Ash Conveyor Operates Under Water

IN MODERN BOILER plants where ample basement room is provided or where tunnels with sufficient head room are provided under the boilers, the problem of handling the ash presents no great difficulties. Conveying systems or ash car systems are easily installed in such places. In older plants, however, not provided with basements or tunnels, the problem is not so easily solved.

A novel method of removing ashes in a plant of the latter type was recently brought to our attention. It made use of an equipment which, we understand, has been used considerably in Europe but not much in this country, in fact, this was one of the first installations.

The plant is that of the Morris and Somerset Electric Co., at Morristown, N. J. This, although an old plant, has been converted into a turbine plant and in spite of its many years of service, is able to show modern efficiencies.

At the time the plant was built, hand fired boilers were installed and of course, no basement was necessary in the boiler house, as the ash was removed from the ash pits by hand and wheeled out in wheel barrows. When mechanical stokers were installed later on, it was impractical to construct a basement due to the ground water and quick sand in the locality. By means of waterproofing and by providing enough dead weight to overcome bouyancy it would have been possible, but this would have been an expensive proposition, and in view of the age of the buildings was not considered advisable.

In order to provide for the easy removal of ashes without the necessity of providing extensive basement space a new type ash conveyor made by the Combustion Engineering Corp. was installed. This conveyor operates continuously and is intended primarily for use with stokers in which the ash is discharged continuously and automatically, such as multiple retort stokers with clinker grinders and traveling chain grate stokers.

It consists of a double chain scraper moving in a trough containing water, the trough being located under the ash discharge of the stoker. Ashes and clinker from the stoker or through the clinker grinder directly into this trough and are quenched and immediately carried along by the conveyor and deposited in a large storage hopper at the end or outside of the boiler room.

The water trough is only about 3 ft. deep and was easily installed under the boilers. An iron trough is usually provided with this type of conveyor, but in this installation a concrete trough was constructed. This was somewhat more expensive but it is believed will give longer service.

Two of these conveyors are installed, side by side in separate troughs, one being held in reserve in case the other should break. The troughs extend the entire length of the boiler room. At one end, outside of the building, the trough inclines upward as shown in Fig. 1 and terminates above the storage pile. As the ash is conveyed up the incline, the water drains back into the trough. The return of the chain is made in the trough, being carried on guide rails attached to the side of the trough as shown in Fig. 3.

FIG. 2. ANOTHER VIEW OF THE INCLINED PORTION OF THE CONVEYOR

The return of the chain is made in the trough, about

FIG. 1. VIEW OF THE DISCHARGE END OF CONVEYOR

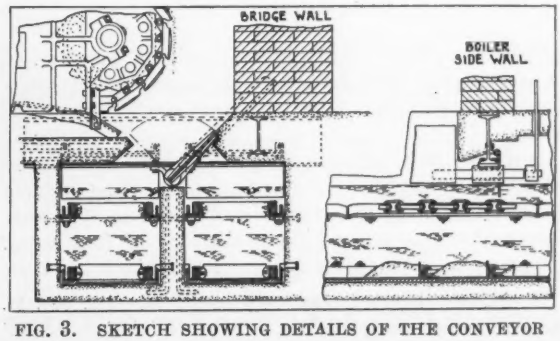


FIG. 3. SKETCH SHOWING DETAILS OF THE CONVEYOR

2 ft. above the lower run. This in no way interferes with the delivery of ashes into the conveyor, as it readily passes between the flights of the return run and falls to the bottom of the trough.

The ash chutes or hopper beneath each boiler terminate in a spout which dips beneath the water of the conveyor, thus providing an absolute seal against the entrance of air at this point, and effectively excludes dust and hot gases from the boiler room or conveyor trough.

As has been stated, there are two of these troughs side by side. In order that the ash may be delivered to one or the other, a swinging gate is arranged as shown in Fig. 3.

Manganese steel is used for the material of the drag shoes. This was found necessary because of the excessive wear experienced with other metals. The gritty ash and water is an effective grinding agent and the softer metals wear away rapidly.

The conveyor is operated by an electric motor through reduction gears, the entire driving mechanism being located on a protected platform above the point of discharge.

Good Feed Piping Prevents Many Boiler Troubles

FLEXIBILITY IS ONE OF THE MOST IMPORTANT CONSIDERATIONS WHEN LAYING OUT BOILER FEED WATER PIPING. BY C. C. HERMANN

WHEN WE THINK of boiler piping it is not uncommon to get the cart before the horse and as a consequence the feed water piping system is left for later consideration. So far in this series* we have concerned ourselves with the steam piping or that portion of the piping between the steam generating units and the prime movers. In the present article we will consider the feed water piping. The principal thing to bear in mind in the design of the feed-water piping is flexibility. The system must be capable of supplying feed water to any one of the boilers at will of the attendants. Certain units will be out of service occasionally which brings about this

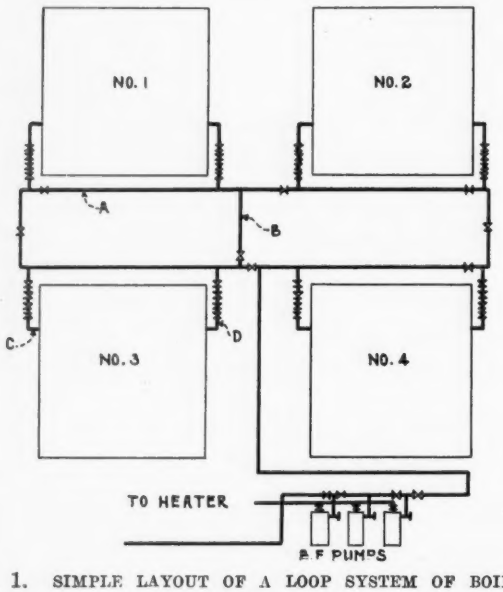


FIG. 1. SIMPLE LAYOUT OF A LOOP SYSTEM OF BOILER FEED WATER PIPING

requirement. The first thing to consider, therefore, is the most logical and economical arrangement of crossovers and bypasses in order to assure continuity of operation.

It is common practice to provide two methods by which water may be fed to the boiler. The method whereby this may be accomplished depends somewhat upon local conditions and the availability of feed water. For example, in one plant I visited, and which is an example of many such plants, a city water connection was made to each boiler in addition to the regular feed-water line from the boiler feed pump. This is only possible where the boiler pressure is low, since city main pressure rarely exceeds 60 lb. In ordinary practice we often find duplicate boiler feed pumps in use and the main piping arranged according to the loop system or the parallel main system.

Figure 1 illustrates the loop system. Here the loop main is shown at A with a single crossover at B for the battery of four boilers. Each boiler is provided with two distinct connections as shown at C, D to the main loop A. Either of the boilers may be taken off the line without affecting the others. The boiler feed pumps are located at the rear of the boilers and may consist of two pumps, either of which may be large enough to take care of the entire plant.

Figure 2 shows the parallel or double-main system of piping for the feed-water system. Generally the main A is used as the regular feed line and the main B as the auxiliary. The main B is kept shut off by the valve C until required. Each boiler is provided with two distinct connections, one of which is to the main A and the other to the main B, as shown at D and E. Sometimes the main shown at A is constructed in a loop, in which case the main B forms a crossover for each boiler. With proper layout the same feed-water regulator, check valves and controls may be used with either the regular or auxiliary main.

CONNECTIONS TO BOILERS ARE IMPORTANT

Various practices are resorted to with regard to the connection of the boilers to the feed water lines; it is good practice, however, to incorporate sufficient valves in the main pipes to enable the removal of any one of the boilers from the line by the use of gate valves, since these are either kept wide open or closed tightly. Considerable trouble is experienced from time to time with these valves, due to sediment, and they often require attention, therefore their number should be kept to the absolute minimum. In the boiler connection there should be a gate valve, a globe type regulating valve if hand regulated, a check valve and preferably a second gate valve to enable the removal for repairs of the regulating valve. In case automatic regulation is anticipated, then the regulator should be provided with a bypass and a hand regulating valve in order to insure continuity of operation in event of failure of the automatic regulator. With the exception of the globe regulating valves it is advisable to

*Attention to Piping Details Saves Steam, page 239, Feb. 15, 1925, issue and Factors in the Design of Steam Piping Systems, page 348, Mar. 15, 1925, issue.

use gate valves, as they offer the least resistance to the water which may flow in either direction around the loop.

Discharge of the feed water into the boiler is well taken care of in the A. S. M. E. code; it may not be out of place, however, to state here that the discharge should be in that portion of the boiler where boiling is least violent and never near a riveted joint or furnace sheet. In return tubular boilers the discharge is carried through the front head and just above the tubes, discharging at a point just beyond the center of the boiler. The head is provided with a screw flange into which the external pipe screws and the water is carried into the boiler by an internal pipe screwed into the fitting. This internal pipe passes along and above the center row of tubes, thereby permitting the water to be heated somewhat before actually discharged into the boiler. This internal pipe must be properly supported.

One other point of importance in the design of the feed water piping is the velocity consideration. The pipe size should be such as will provide a maximum velocity of 400 ft. per min. It is customary to use extra heavy pipe and fittings for pressures over 100 lb. Not infrequently we find the brass fittings between the boiler and main. They are used to avoid the corrosive action which takes place in iron piping and fittings.

Probably the simplest piping arrangement for feed water is found in non-condensing plants when the water is obtained under a slight head after having been heated in an open feed-water heater. From the pumps the heated water is forced to the boilers or through economizers if they are used. If a feed-water meter is used it is installed preferably on the discharge side of the pump and so crossed over that it may be removed for repairs without rendering the system useless. Where the return water is used it is usually piped directly to the heater or hot well where the make-up water is supplied.

Location of a Closed Feed-Water Heater

One point to bear in mind is that every fitting used adds materially to the friction head that must be overcome. For example, 200 gal. per min. through four elbows, two globe valves and 400 ft. of 4-in. pipe gives a total resistance head of 13.25 ft. of water or 5.75 lb. per sq. in. when discharging into an open tank. To this must be added the resistance of the meter, an economizer where used, purifiers and the heater resistance where a closed heater is used. It might be well to mention here that where the feed water is not under a pressure head the closed heater is preferred to the open heater. The heater is then placed in the pump discharge line between the pumps and the main pipe. Live steam purifiers are used where the feed water contains a large percentage of calcium sulphate, in which case the feed water is subjected to the boiler pressure and temperature, thereby precipitating the impurities before injecting the feed into the boiler. Bypasses should be provided to cut out such equipment as purifiers, heaters, economizers and meters because repairs are often required on these units.

Suction of the feed pump must also receive its share of attention. It should be as short as possible and with the least number of elbows and valves. Where the closed heater is used and installed on the discharge side of the pump, the handling of hot water, which often flashes into steam under the vacuum condition produced by the pump, is eliminated. In the latter case, the make-up water is added ahead of the pump so that the temperature of the pumped water is fairly low.

The blowoff is used for clearing the boiler of mud and sediment and emptying the boiler of water whenever desired. It enters the boiler at its lowest point. Another blowoff connection, known as a surface blowoff, is often provided to perform a similar function at the surface of the water. In the return tubular boiler the blowoff is located at the rear and in the bottom of the shell. It passes through the rear wall whereas boilers supplied with a mud drum have the bottom blowoff located in the lowest portion of this drum.

I have personally experienced considerable trouble with globe valves in the blowoff line. Sediment or a chip of encrustation becomes lodged on the seat of the valve and it cannot be tightly closed. Here we may find that a bypass is a good thing but its use has been almost eliminated by the use of properly designed blowoff valves. In fact, the bypass is hardly to be recommended since it, together with the globe valve sometimes installed, exceeds the cost of a far superior blowoff valve. Many boilers are still in use in which a brass plug cock is found in the blowoff, however, on high pressure work these have been mostly super-

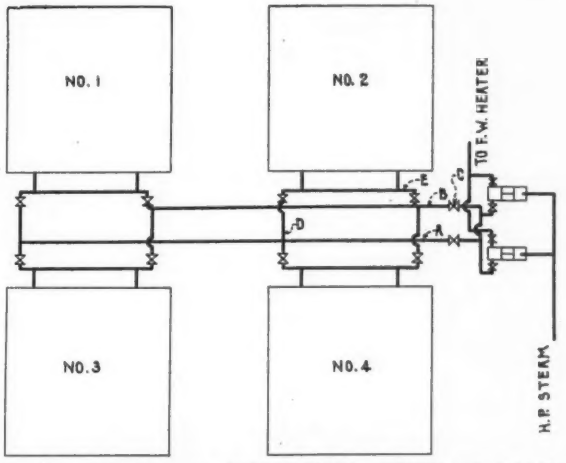


FIG. 2. PARALLEL OR DOUBLE-MAIN SYSTEM OF BOILER FEED WATER PIPING

seded by especially designed gate valves. The brass plug valve supplied with an asbestos packing is preferable to the ordinary plug due to the latter sticking.

Discharge of the blowoff must be investigated thoroughly before reaching a decision. In some localities the discharging of the blowoff into the sewers is not permissible and a blowoff sump must be provided. At any rate the discharge should be at a lower point than the boiler connection.

Just as the bottom blowoff is used to remove sediment from the lowest point of the boiler so the surface blowoff is used to remove the sediment and impurities which float on the surface of the water within the boiler. A shallow trough is sometimes provided in the boiler to collect the scum and direct it to the outlet. The surface blowoff can be connected by a tee to the same external pipe as the bottom blowoff. This pipe should be protected from high temperature gases the same as the bottom blowoff. One way to accomplish this is to place a large pipe over the blowoff pipe and pack the space between the two pipes with asbestos.

Methods of Obtaining a Heat Balance---I*

RELIABILITY, ECONOMY AND SIMPLICITY ARE FACTORS WHICH SHOULD BE GIVEN DUE CONSIDERATION

MANY possibilities are available when it comes to the arrangement of equipment for a heat balance. It is of course, to be understood that not every arrangement can be best adapted for any one problem. The type of plant often dictates the hook-up for the heat balance; again existing condition may greatly alter the problem. Space limitations may also be a controlling factor and personal preference may have some bearing on the problem. The arrangements given in this series of articles will be of interest to those engineers who are confronted with the varied problems of power plant design.

Figure 1 shows an arrangement wherein water is withdrawn from the condenser hot well and forced through a

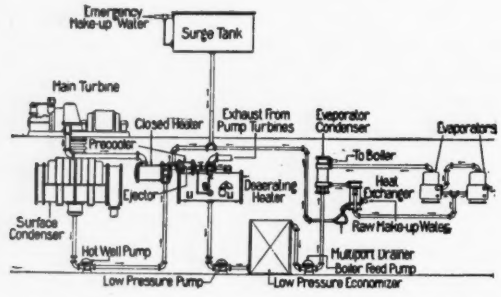


FIG. 1. PUMP DRAWS WATER FROM THE DEAERATOR AND FORCES IT THROUGH A LOW PRESSURE ECONOMIZER

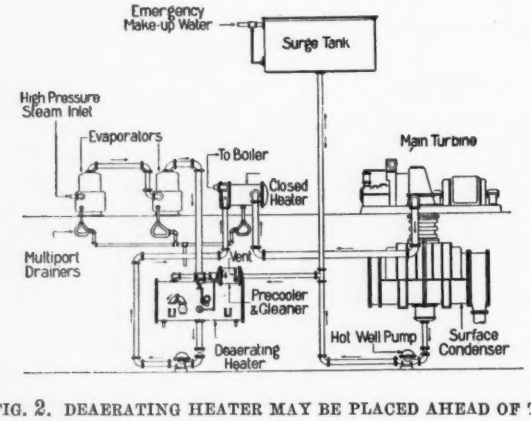


FIG. 2. DEAERATING HEATER MAY BE PLACED AHEAD OF THE BLEEDER HEATER

closed heater which receives steam from the bleeder connection on the main turbine. The water then goes to the deaerating heater which is supplied with steam from the turbine and engine driven auxiliaries. In order to control the water supplied to the heater, a float operated valve is used. Just ahead of this valve is a connection to the surge tank which provides for the variations in rate of boiler feed. Make-up water supply to the surge tank is controlled by a float valve.

Water withdrawn by means of a pump from the deaerator is forced through the low pressure economizer to the boiler feed pump which then forces the water through the evaporator condenser and into the boilers. Distilled water from the evaporator condenser and the steam coils of the evaporators is discharged to the surge tank. It is necessary to vent the deaerator heater and this is done by a steam ejector which discharges into a small vent condenser or heater combined with the pre-cooler. The air and vapor are reduced in temperature in this precooler before reaching the ejector.

Arrangement shown in Fig. 2 is essentially the same as Fig. 1, the difference being that the deaerating heater precedes the bleeder heater in the feed water circuit and it receives steam from evaporators rather than from the auxiliaries. This scheme is not as efficient for deaerating as is that described first, because the temperature in the deaerator is not as high.

Still another arrangement is that shown in Fig. 3 in which the deaerating heater is preceded by two bleeder heaters and is followed by a third. A thermostatic valve controls the amount of steam taken from the main turbine for the second bleeder heater. In this way, the temperature of that heater is held constant, regardless of the variations in the supply of steam from the auxiliaries. This also assures a constant pressure in the auxiliary exhaust line.

It will be noticed that both an elevated and a low level storage tank is used. The surge tank receives the make-up water and condensate from the hot well. It supplies water to the deaerating heater and also to the oil coolers from which the water passes to the storage tank and is returned to the surge tank by a service pump.

In industrial plants where large quantities of low pressure steam are used in processes or for heating, turbines

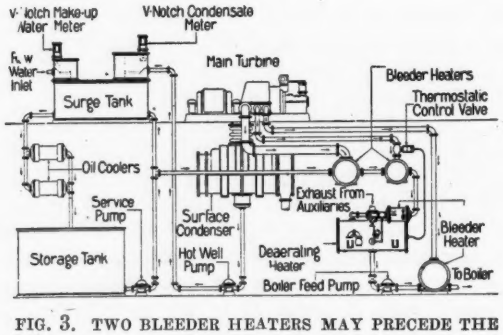


FIG. 3. TWO BLEEDER HEATERS MAY PRECEDE THE DEAERATING HEATER

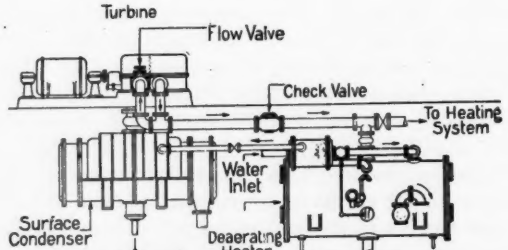


FIG. 4. SOLID DIAPHRAGM MAY SEPARATE THE HIGH AND LOW PRESSURE STAGES OF THE TURBINE

*Abstracted from "Heat Balance Hookups," copyrighted by the Cochrane Corporation, Philadelphia.

may be so constructed that the high and low pressure stages are separated by a solid diaphragm so that steam from the high pressure side must pass through a flow valve before entering the low pressure side or stages. This valve serves to hold a fixed minimum pressure in the deaerating heater and in all the low pressure steam using system supplied with bled steam. Figure 4 shows such an arrangement which is of particular advantage where bled steam is used for low pressure heating or process work.

Auxiliary exhaust may be connected into the low pressure line, in which case a check valve should be placed near the turbine to prevent backflow. The vent from the deaerating heater may be connected to the main condenser. A precooler is usually installed in the vent line, thus absorbing the heat of the steam-air mixture by the inflowing cold water.

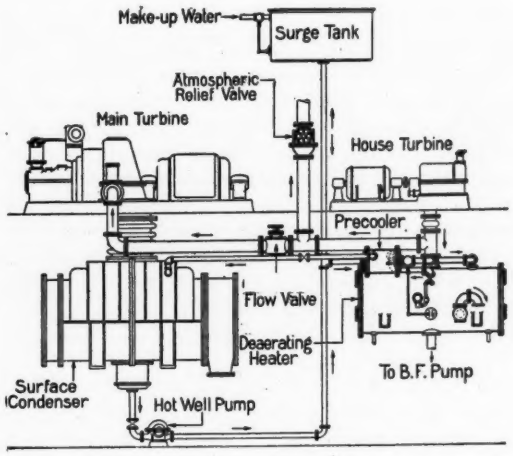


FIG. 5. LOAD ON THE HOUSE TURBINE MAY BE RELATIVELY CONSTANT

One scheme where the deaerating heater is supplied by steam from a house turbine is shown in Fig. 5. Here it will be found that the house turbine load is usually relatively constant even though there may be wide variations in the load on the main unit and, therefore, in the amount of condensate which must be heated. If all the exhaust steam from the house turbine was used to heat this condensate, the temperature would vary over an extremely wide range. To overcome this difficulty, a flow valve may be used so that the steam in excess of that required for feed heating will be returned to the low pressure stages of the main turbine. The governor of the main unit will control the steam to it and an atmospheric relief valve should be connected to the house turbine exhaust pipe.

General arrangement of Fig. 6 is similar to that of Fig. 5, except that it is assumed that the exhaust steam available from the house turbine is at times less and at other times more than that required by the heater. This situation may be handled by connecting up an intermediate stage of the main turbine with a pressure reducing valve, so that should the pressure in the heater be lower than the pressure in that stage, a supply of steam will be bled from the turbine. Reverse flow towards the turbine may be arranged for by placing a check valve in shunt with the pressure reducing valve. In this way, should the house turbine exhaust pressure be higher than that in the bled stage of the main unit, the excess steam will flow to the intermediate stages of that unit. No steam is wasted, since a continuous heat balance is maintained. It is readily seen that the temperature of feed water can never be higher than the temperature of the steam in the main turbine connection and at times of heavy load, when the temperature of the feed water might fall if heated only by the auxiliary turbine exhaust, it cannot drop below the fixed limit of the pressure reducing valve. It is necessary to governor control the bleed connection on the main unit in order that over-speeding may not occur.

Figure 7 shows another arrangement wherein the steam for the heater comes from an evaporator, which receives steam from the main turbine bleeder, as there is no direct connection between the bleeder opening and the interior of the heater. It is necessary in an arrangement of this kind to make the bleeder connection from a turbine stage in which the pressure is sufficiently high to provide the temperature differential needed to force the required amount of heat through an evaporator heating surface. The path of the water is from the deaerating heater through a closed heater and then to the economizer or boilers. The closed heater is connected to the same bleed connection as is the deaerating heater. In this way, the boiler feed water is heated to about the temperature of the bleed steam. With this arrangement a certain amount of evaporated make-up is obtained without loss in plant efficiency as compared with the same plant having a single bleed heater but no evaporator. It is interesting to note that in this case the deaerating heater serves as the condenser for the evaporator.

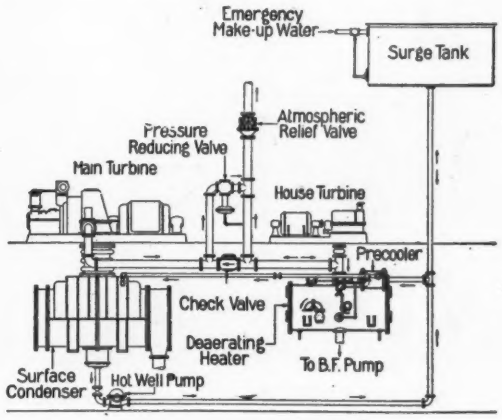


FIG. 6. PRESSURE REDUCING VALVE MAY BE AFTER THE INTERMEDIATE STAGE CONNECTION

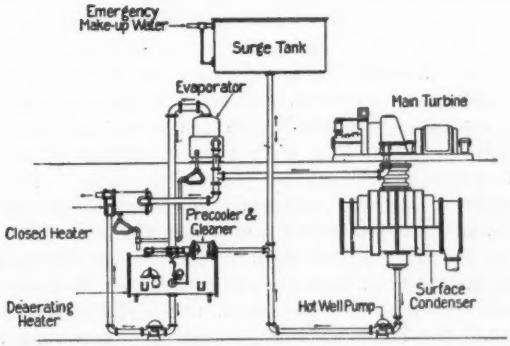
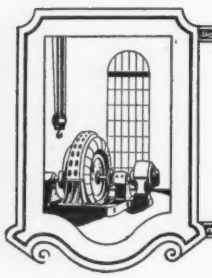
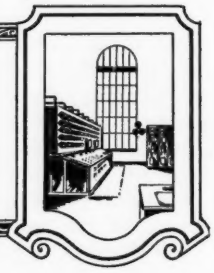


FIG. 7. IT IS NOT NECESSARY TO HAVE A DIRECT CONNECTION BETWEEN THE BLEEDER OPENING AND THE INTERIOR OF THE HEATER



ELECTRICAL MACHINERY FOR LIGHT AND POWER



Outdoor Substation Practice

NOTES ON MODERN PRACTICE; FACTORS AFFECTING DESIGN. DESCRIPTION AND PRINCIPLES OF ELECTRICAL EQUIPMENT

IN THE DESIGN of substations and switching centers for high voltage transmission systems the use of outdoor equipment has become the accepted standard. There are several reasons for this; first because of the excessive clearance required by high voltage conductors the cost of constructing suitable housings has become prohibitive. Second, the provision of housings over high voltage equipment introduces a number of hazards in bringing in leads, all of which are eliminated with the outdoor type of construction. Third, stationary transformers, oil circuit breakers, lightning arresters and associated apparatus as it is made today is sufficiently protected by its own housing that no additional protective covering is necessary. In many cases, where service from high voltage transmission systems is to be given to isolated customers, the outdoor station is the only possible solution to the problem since the construction of an indoor station would not be justified from an economic standpoint. Another advantage of the outdoor station lies in the ease with which it can be modified or enlarged.

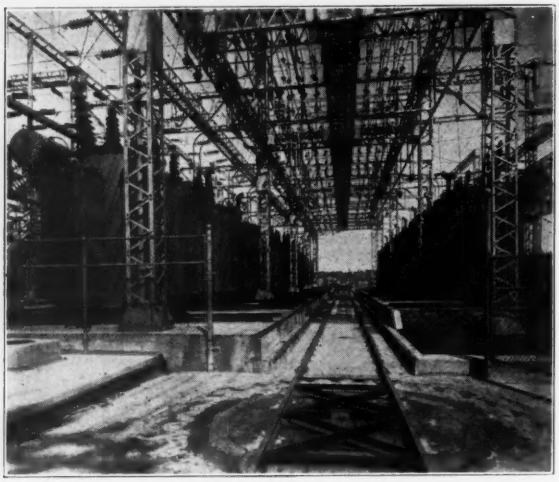


FIG. 1. AN EXCELLENT EXAMPLE OF LARGE OUTDOOR SUBSTATION CONSTRUCTION

In general, outdoor stations are of two classes, stations designed for one predetermined load with no extensive provision for switching, and switching centers, designed for handling a large number of incoming and outgoing lines with means for transformation of wattage. The former are usually simple, consisting of a transformer bank supplied from a high voltage transmission line with suitable provision for lightning protection and disconnecting switches for isolating the transformers and protective equipment from the line. Such disconnecting switches are as a rule not intended for opening the circuit under load, although recently several manufacturers have brought out air break switches of moderate capacities intended for breaking the circuit under load. It is also desirable in many instances to provide automatic oil circuit breakers or fuses for protecting the system in case of trouble due to short circuits or grounds. Measuring instruments and metering equipment, if required, are installed in a cabinet at the substation or on the customers' premises.

The switching center type of station is considerably more elaborate, larger and presents far greater engineering problems. They usually have to be designed to suit the particular requirements of a certain installation, and while standard equipment and standard forms of assembly can be used to advantage each case requires individual study. Considerable progress has been made in standardizing the "particular load" type of station. The demand for power by small villages, farming districts and isolated manufacturing plants has opened a large field for this class of equipment and since the requirements for each service are more or less uniform, standardization is not difficult.

A substation of the particular load class is shown in Fig. 9 and in Fig. 10 are shown the details of an installation of this kind. It consists of a structural steel frame work at the top of which are mounted high tension air break switches, high tension fuses, lightning arresters and choke coils. Below, on a concrete base are the three step-down transformers. The installation illustrated in Fig. 9 serves a mining property, but the same general arrangement is adaptable to almost any type of manufacturing plant.

In smaller installations an even simpler arrangement is used, and instead of a steel framework, the entire equipment, including transformers, may be mounted between two or more wood poles, tied together by wood or steel cross members. If the transformers are large they are set on a concrete base as explained above, but if of relatively small capacity they are placed on a platform supported by the structure some distance below the top, where the lightning arresters, fuses and switches are located. This type of equipment is particularly suitable for rural service because of the small investment necessary. The heavy construction employed in large city distribution is not necessary for this rural service and certain light forms

of standardized equipment have met with considerable favor in this field. In Fig. 3 is shown a standard unit put out by one manufacturer designed for this class of service. It consists of a horn gap lightning arrester with series resistance to ground in combination with a disconnecting switch, choke coil and high voltage fuse. The whole is constructed as an integral unit all ready for mounting on the supporting framework. For a three phase circuit three such units are required.

Large Outdoor Installations

In the construction of large outdoor substations, the permanency and strength of structural steel has led to its almost universal adoption. Even in cases where wood pole

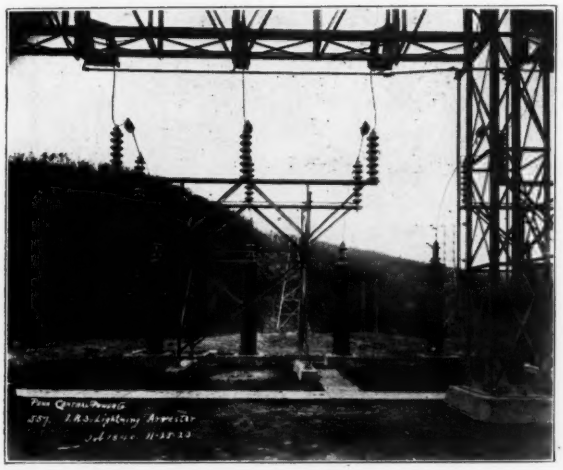


FIG. 2. AN INSTALLATION OF LIGHTNING ARRESTERS AT AN OUTDOOR SUBSTATION

transmission lines have been used, it is found economical to erect steel structures for switching and transformer stations. Steel makes possible the most efficient arrangement of apparatus and operating mechanisms, presents a more sightly appearance and has great advantages in strength and durability over wood.

There are two classes of steel structures, the heavy member type and the fabricated type. The former type is probably somewhat higher in total cost than the latter, due to a less economical use of material, but it has the advantage of greater ease in erection. The foundations are simpler and there are fewer pieces to handle, although there will be greater difficulty in handling pieces due to their weight.

The fabricated type of structure usually costs more per pound of material, but the total weight can be made considerably less than the heavy member type. The members, too, can be made stiffer and long spans are more practical, an extremely important consideration in high voltage work. Another advantage of the fabricated type is that the parts can be bolted together in the field.

An excellent example of the fabricated type of structure is shown in Fig. 1, which is the Lenore Station of the Indiana Electric Corp. near Indianapolis, Ind.

Figure 7 is a photograph of a smaller type of structure using rigid members. This is an installation of the Wisconsin Valley Electric Co., of Wausau, Wis., for three 44,000/22,000/2300-v. power transformers, each rated at 1750 kv.a. All modern equipment is used, oxide film lightning arresters, air break switches, high potential fuses, reactors, potential and current transformers and oil circuit breakers. The latter it will be noted are mounted on a heavy steel framework some distance above the ground, so as to permit the oil containers to be lowered without disturbing the contacts. This permits the oil to be changed and the tanks cleaned with minimum effort. The insulators for supporting the conductors are exactly the same as those used with the disconnecting switches, lightning arresters and fuses and are therefore interchangeable. This is an important feature as it reduces the number of spare insulators to be carried. The combination brace type choke coil and air break disconnect mounted on one base is seen at the top of the structure to the right.

Factors Affecting Design

The design of an outdoor substation installation is governed largely by the particular requirements of the case and by local conditions. Available space, topographic, climatic or geologic conditions all have an indirect bearing on the design. Naturally, such factors as capacity, voltage, direction of incoming and outgoing lines, type of equipment have a direct bearing and therefore need thorough consideration. Particular attention should be given toward obtaining the most rigid arrangement of steel that can be obtained. In many instances, by the use of

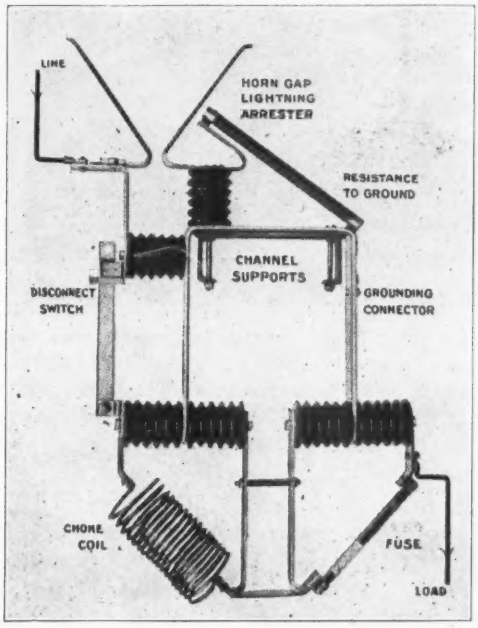


FIG. 3. STANDARD UNIT FOR SMALL OUTDOOR SUBSTATIONS

adequate bracing, it is possible safely to reduce the sizes of the main members, resulting in an ultimate saving in the weight of the structure.

The question of loading is of great importance. A frame that is insufficiently braced will fail when subjected to severe loading. In regions of severe sleet, and where high winds are prevelant, a heavier style of design is necessary, as is also the case when long spans are dead ended on the station itself.

In any case it is advisable to leave the design of the steel structure itself to a structural engineer, the electrical engineer providing him with the necessary sketches showing the desired arrangement of electrical equipment. The

Views of Typical Outdoor Substations

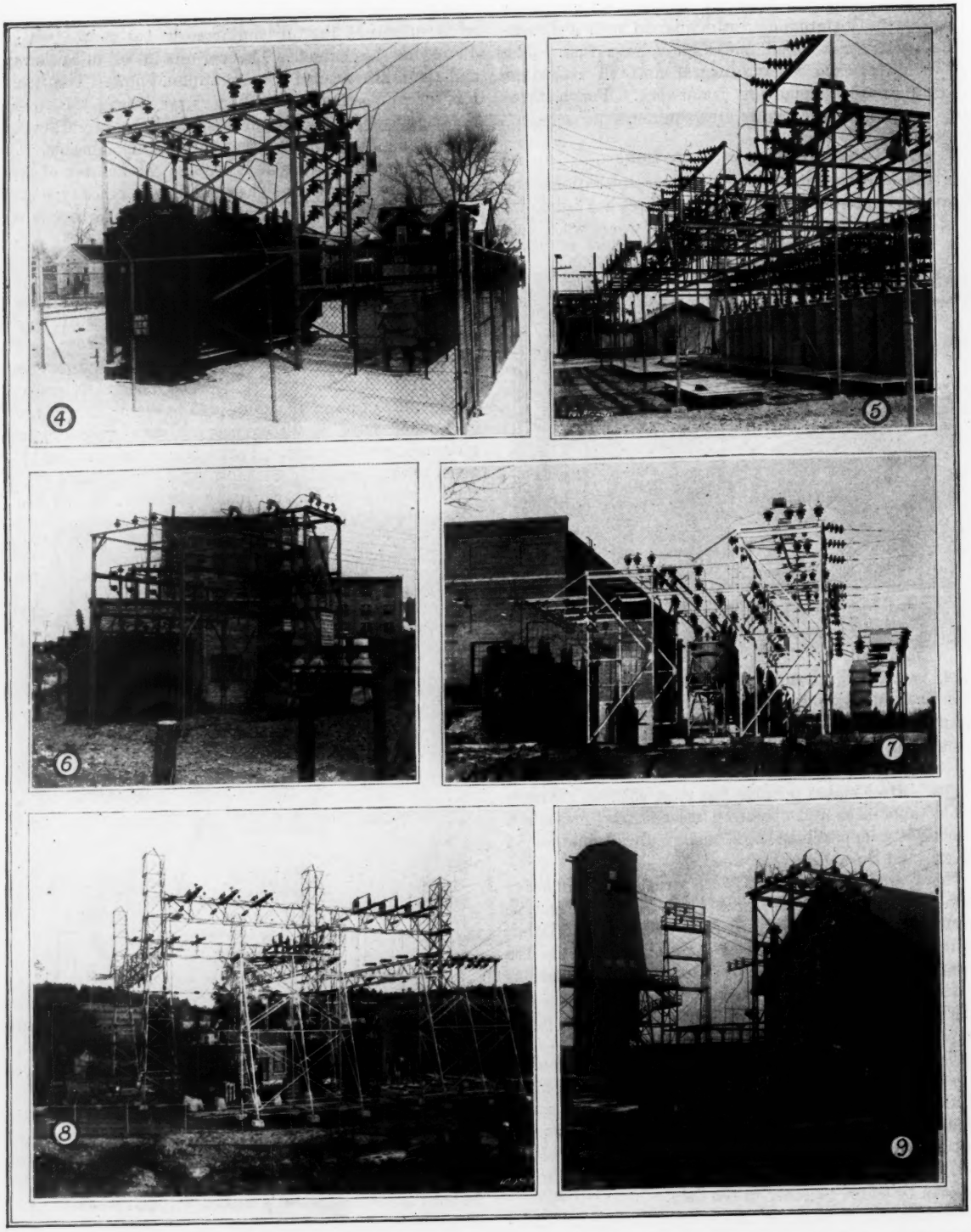


Fig. 4. An installation of transformers serving a residential district from a 33,000 v. transmission line. Fig. 5. The Los Alamitos substation of the So. California Edison Co., 4500 kv.a., 60,000/11,000 v. Fig. 6. A view of a typical industrial type of transformer substation. Fig. 7. The outdoor station equipment of the Wisconsin Valley Electric Co. with three 44,000/22,000/2300 v. power transformers, together with oil circuit breakers, current and potential transformers and protective equipment. Fig. 8. Substation equipment of the Georgia Railway Power Co., Marietta,, Ga. Fig. 9. Substation equipment serving a mine. This is a good example of the particular load type of station.

structural engineer is more familiar with the most effective methods of design and will be able to design a better structure than the electrical engineer, whose knowledge of structural design is a side issue.

A question of considerable importance is that of finish; shall the structure be galvanized or painted? As a general rule, if the station is to be in service for ten years or more, it should have all steel galvanized. At any rate all bolts, nuts and small hardware should be galvanized. Even where the structure is painted, it is best to specify galvanizing for all members supporting live parts on account of the difficulty of painting them while the line is hot.

If galvanizing is used there should be no riveted joints, and no field drilling of members should be permitted. But practice demands that all pieces shall be separate and bolted together.

Painted structures lend themselves to shop riveting of trusses and gusset plates which is an effective method of stiffening the structure.

Electrical Equipment Used on Outdoor Substations

The problem in selecting conductors for primary connections and bus bars on outdoor stations is one of securing a conductor that will not sag of its own weight with distances between supports of from 10 to 25 ft. In practice various things have been used but the use of tubing, either copper or iron seems to have met with greatest favor. Several companies have developed special types of conductors such as two angles secured back to back with a spacer between to allow the insertion of a connection. Where the spans are short and the currents small, bare copper wire is used. In most cases, however, mechanical strength rather than current carrying capacity is the determining factor in designing the primary electrical system, and pipe has many advantages over other forms of conductors.

For secondary circuits, weatherproof insulated wire is often used although except for purposes of differentiating the secondary conductors from the primary there is no reason for insulation. In Europe the practice of painting the conductors is common. All primary conductors are painted red, secondary green or blue.

Ordinary disconnecting switches are intended merely for the purpose of isolating circuit breakers, lightning arresters and other equipment, after the circuit has been opened by some other means. Disconnecting switches are usually furnished as single pole units for hook stick operation, or as multiple units with a remote hand or power operated mechanism. Such switches, unless furnished with arcing horns, are intended for use only on de-energized circuits. When provided with arcing horns, they may be used to break the arc resulting from the charging current of the line, magnetizing current of a transformer bank, or a small power load within the rupturing capacity of the switch.

Recently, several manufacturers have developed air break switches designed for operation under moderate loads. These are usually quick acting switches with provision for transferring the arc formed in breaking to a horn gap arrangement where the final break occurs. Such equipment naturally is considerably lower in cost than oil circuit breakers and on small systems where the load is moderate has given satisfaction.

High voltage fuses have been in general use for over 12 yr. and have found extensive application in all classes of service, both indoors and outdoors, on circuits up to

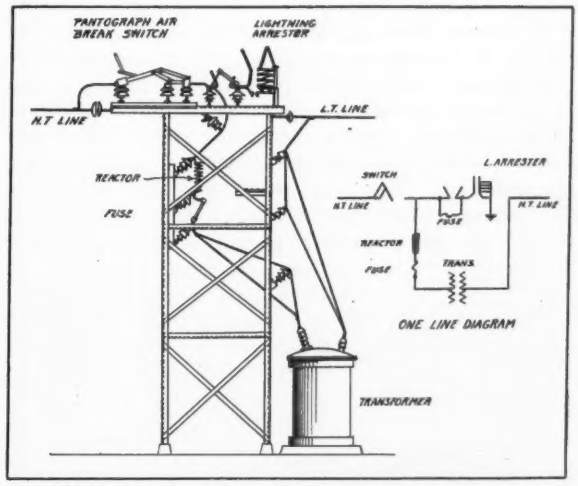


FIG. 10. DIAGRAM SHOWING ARRANGEMENT OF EQUIPMENT ON SMALL OUTDOOR SUBSTATIONS

115,000 v. They are made in capacities up to 400 amp. Such fuses are considerably cheaper than oil circuit breakers and are extremely rapid in action.

They can be used to advantage for the protection of both small and large capacity substations. If switching under load is not a necessary requirement, full protection can be obtained with fuses at a much lower cost than with oil circuit breakers and the layout of the station will be simpler.

The exceptionally rapid action of high voltage fuses permits overfusing the transformers considerably above normal current. In actual practice from three to ten times normal is used depending upon local conditions. For power circuits subject to wide fluctuations such as mining loads, the high tension circuit should be so rated or adjusted that they will not operate except in case of actual trouble. Such overload protection as is desired can be secured easily and cheaply by means of a low tension switch on the secondary side of the transformer bank. In substation practice, this combination of heavy high tension fuses on the primary side which will open only in case of transformer failure and a properly adjusted oil circuit breaker on the secondary side of the transformer bank is an excellent protective system.

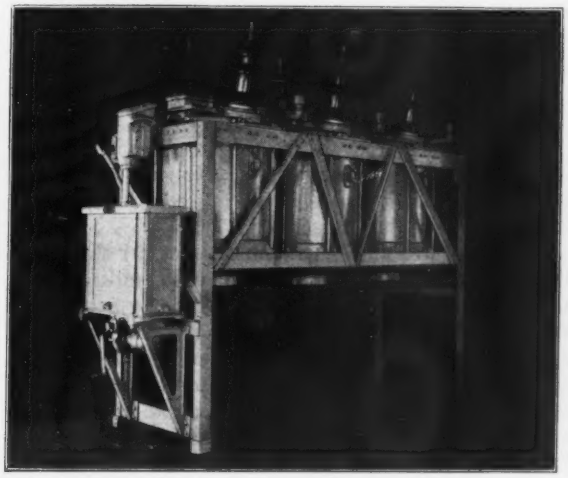


FIG. 11. THREE PHASE OIL CIRCUIT BREAKER FOR OUTDOOR USE

High potential fuses are often used to provide safety to the operator when opening disconnecting switches. The opening of disconnects is always a hazardous task since even with the most elaborate precautions to insure that the particular circuit to be opened is dead, there is always the possibility of opening the wrong switch. The provision of high voltage fuses in this connection insures positive protection. The usual arrangement is to shunt the disconnecting switch by a low amperage fuse, so installed that the disconnect cannot be opened unless the fuse is in

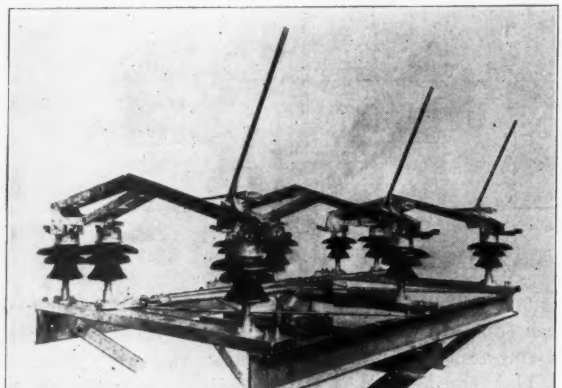


FIG. 12. THREE POLE AIR BREAK SWITCH DESIGNED FOR OPERATION UNDER LOAD

place. If the disconnect is opened when the circuit is alive, the current is shunted through the fuse where it is interrupted when the fuse blows, due to the current being above the rated current of the fuse.

Lightning Arresters

Lightning arresters form an essential part of all outdoor substations and transmission centers. These may be of the electrolytic type, the oxide-film, the auto-valve the resistance type or the water vapor cushioning type, depending upon the class of service. Where the equipment is given daily attendance, the electrolytic type of arrester will give excellent satisfaction. It has the disadvantage of requiring frequent charging that is a re-establishing of the resistance film by momentarily connecting it to the line. In cases where daily attendance can not be given, therefore, it is necessary to use one of the other types.

The resistance type of arrester has the advantage of simplicity and compactness. It can, as a rule, be installed as a unit together with the horn gaps and fuses, at any place on the substation structure.

The auto-valve and oxide-film type of arresters were developed in an effort to obtain a flexible valve arrester which was at once compact, effective and did not require attention. The pellet type of arrester is a modification of the oxide film type. All of these have come into wide use, not only in outdoor substation practice but for general protection of distribution lines as well.

In the installation of lightning arresters, the question of obtaining an effective ground connection is highly important. In fact, the ground connection is one of the first things to be considered, even before placing the foundation. It has often been pointed out that if the ground resistance is high no arrester can give good results. The grounding of lightning arresters and transformer cases is not a thing that may be neglected until the last minute, but must be given attention as soon as the necessary excavations for the job have been made. In proper soil, driven pipe or rod can be made satisfactory. More elaborate grounds are sometimes justified where reasonable driven grounds cannot be made. Where good grounds are difficult to make, even by driving multiple pipes or rods, the only way to obtain a satisfactory ground is by burying a large ground plate at a considerable depth in prepared soil.

After the ground connection has been made the resistance should be measured and thereafter checked monthly.

Transformers and Circuit Breakers

Transformers and oil circuit breakers for outdoor substation are not different from the usual indoor type of equipment except that they are fitted with weatherproof casings. Circuit breakers for this service are made with interrupting capacities up to 1,500,000 kv.a. They may be manually or electrically operated and arranged for automatic reclosing service a.c. or d.c. of one or more closing cycles, with constant or varying time delay.

Choke coils are usually simple cylindrical inductances, mounted on suitable insulators. In some cases the choke

FIG. 13. 70,000 V. TRANSFORMER SUBSTATION OF THE PENNSYLVANIA WATER & POWER CO., HOLTWOOD, PA.

coils are designed for insertion in the line itself without any support, these being known as the suspension type. Such coils have a strain insulator of wood or other insulating material passing through the center, to relieve the coil itself of any stress.

These choke coils present no appreciable reactance so far as the normal frequency current is concerned. To a high frequency disturbance they present great impedance, thus diverting such disturbances to the lightning arresters.

Conclusion

In concluding this article we extend credit to the following manufacturers who generously supplied us with photographs and valuable technical information used in its preparation: Westinghouse Electric & Manufacturing Co., Schweitzer and Conrad, Inc., Condit Electrical Mfg. Co., Electric Power Equipment Corp., the General Electric Co., and the Delta-Star Electric Co.

Principles of Induction Motor Action

PRODUCTION OF ROTATING MAGNETIC FIELD; GENERATION OF CURRENT IN ROTOR. REACTION OF ROTOR CURRENT UPON STATOR CURRENT. BY CHARLES G. GREEN*

ALTERNATING CURRENT motors may be classed in general as induction motors and synchronous motors. These can be divided into separate classes as split phase, induction, repulsion induction, single and polyphase induction, and also the compensated repulsion motor. The synchronous motor is in a class almost of its own, with the exception of synchronous converters. The induction motor is about the simplest motor built, the most sturdy, and with no sliding contacts, it is far more commonly used for industrial purposes than any other type of a.c. motor.

In general an induction motor consists of a stationary element called the stator, through the windings of which is sent the alternating current from the line. The rotating element has embedded in its periphery, or surface, copper bars uninsulated from the iron core, and short circuited at both ends by various designs of short circuiting rings. In some cases the ends of each bar are threaded and a ring with as many holes as we have bars is slipped on and bolted. More often the bars are welded to the rings and in many cases the entire squirrel cage, as it is called, is punched in a flat piece and then bent around or fitted on the rotor with a bar in each slot and the ends riveted or welded together.

PRINCIPLE OF ROTATING MAGNETIC FIELD

As was explained in a previous article (Jan. 1st.) the rotating field of a polyphase or split phase induction motor sets up a flux which, as it rotates, cuts across these bars of the rotor. When the rotor, or secondary as it is sometimes called, is at rest, the flux from the rotating field cuts the conductors of the rotor at a high rate of speed. The bar or bars of the rotor that are being cut by the flux from a north pole, have induced in them a voltage in one direction, while the bars being out by the flux from a south pole have a voltage in the opposite direction. As stated before, all these bars are connected together both mechanically and electrically. It can be seen by this that with voltage generated one way in one and the opposite way in another would create a large flow of current when connected together at the ends, as shown in Fig. 1. If reference is made to the d.c. generator and d.c. motor, then the induction motor will be clear and simple. As explained before, the chief principle of the induction motor is its rotating field which is produced by the alternating current through its windings. As the current through the different coils which form the field reverses, it changes a north pole to a south, and a south pole to a north. Let us assume that the motor is so connected as to have a field rotating in a clockwise direction, that is, a pole which was north at any one point changes to a south and the pole next to it in a clockwise direction was south, and it is changed to a north. It can be seen then that the magnetic north pole was just shifted over to a position farther on in a clockwise direction and the same action took place with the pole that was south, or in other words, it was also shifted over to a new position.

In a single phase induction motor a whole pole reverses at one time, and with a polyphase induction motor each pole is made up of a number of coils connected to the various phases and its polarity does not change all at once. It can be said, for example, with a three phase motor only one-third of the pole reverses at a time. Or as is shown in Fig. 2, we have a shifting effect much the same as a wave of water shifting over the surface.

If we just straighten out the field structure until it shows 8 poles with current at some one instant so as to produce on the pole the polarity shown in part "b" of the above diagram, our main pole will be made up of three like polarities at all times. Now if phase "C" is the next one to reverse, it will change the polarity of the coil

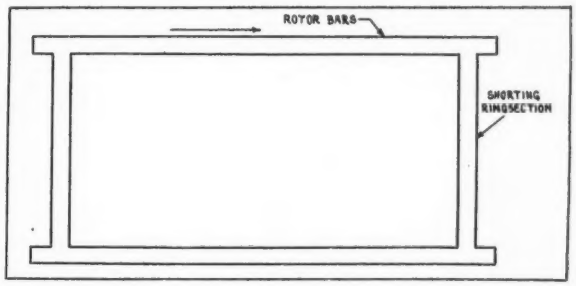


FIG. 1. DIAGRAM SHOWING CURRENT IN ROTOR BARS

on each pole which is fed by it. Part "c" of the polarity lettering shows the changed polarity of the coils and the way in which the main poles have all been shifted one-third of their width over to the right. Now if phase "B" is the next to reverse, we will have the polarities of all the coils fed by it reversed, and as shown in part "d" the main poles are also shifted another one-third of their width to the right. The north main poles are enclosed in dark lines, to make them show up in contrast to the south poles. If we reverse "A" phase, which is next to reverse, then our main poles would have been shifted one whole pole to

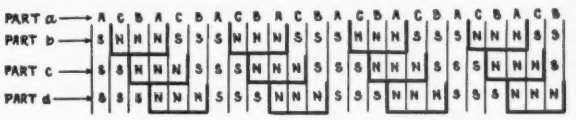


FIG. 2. DIAGRAM SHOWING PRODUCTION OF ROTATING MAGNETIC FIELD BY THREE PHASE CURRENTS

the right, and as explained elsewhere in this article, the number of pairs of poles and the frequency of the a.c. will determine how many times any one pole will be shifted entirely around the field structure in a minute.

GENERATION OF CURRENT IN ROTOR CIRCUIT

With this rotating magnetic field we get practically the same results as if the entire field frame of a d.c. generator was to be rotated. Suppose the pole pieces of the generator in Fig. 3 were rotated in a clockwise direction as indicated by the arrow. Now if the field is rotated clockwise and the conductors are stationary, we will have the same direction of voltage induced in the conductors as if the conductors were rotated counter-clockwise and the field were stationary. In either case the voltage will be generated

*Instructor in motor department, Coyne Electrical School.

"in" as represented in all conductors under the south poles and "out" as shown in all conductors under the north poles. The direction of these voltages can be found by various rules, one of which is quite standard and well known as Flemming's right hand rule for the generator, which is as follows: Place thumb, forefinger and remaining fingers at right angles, and let the thumb indicate motion of the conductor, forefinger the direction of magnetic flux (which is always assumed to leave the north pole and enter the south) and the remaining fingers will point in the direction of induced or generated voltage. Now by reference to Fig. 3 and by application of the rule, we find that the voltage in conductors of the rotor will be induced in the direction indicated. Remember that the field rotating one way, or the rotor the opposite way, will generate the same voltage and for using Flemming's rule we must assume that the rotor rotates opposite the field. Now if

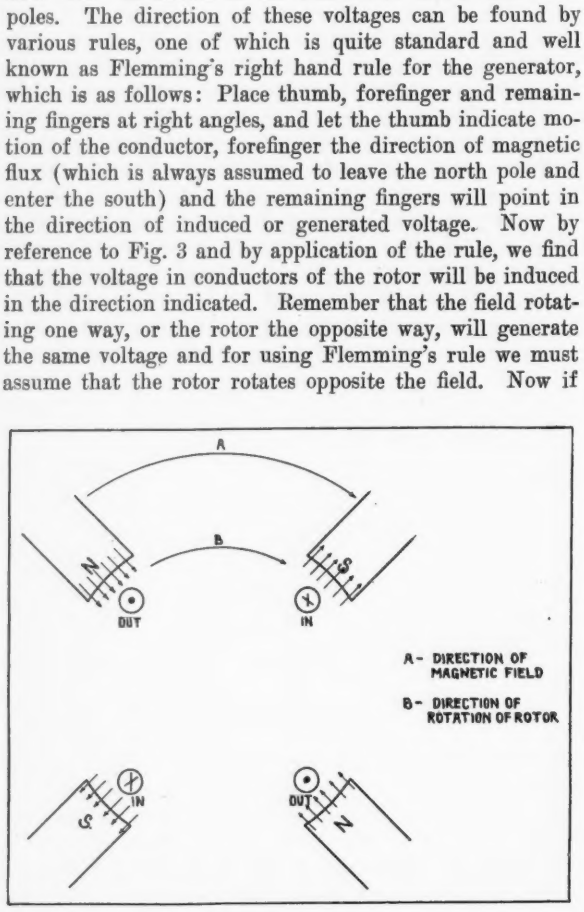


FIG. 3. FIELD POLES AS SET UP BY STATOR CURRENT AND DIRECTION OF ROTATION

we use Flemming's left hand rule for the motor we can determine which way the rotor will rotate. If we have current flow in the direction of the induced or generated voltage, and if we have all these conductors shorted together with voltages opposite one from another, we will have a heavy current flow in the direction of voltage, due to the low resistance path.

With the d.c. motor we had it explained that the flux built up around the armature conductors reacting upon the field flux causes rotation. If that holds good for d.c. motors then it must hold good with the induction motor. And to determine the direction of rotation for a motor we use, as said before, Flemming's left hand rule for the motor, which uses the same position of fingers and the same symbols for each, but using the left hand instead of the right hand as we did with generators. Now by applying this rule we find that by placing the forefinger in the direction of flux, or pointing out from the face of a north pole toward the rotating element, the remaining fingers in the direction of current flow in a conductor directly under the pole face, our thumb will indicate the direction this conductor will be moved. And it shows that this conductor will be moved in the direction of the rotating magnetic field. From this it looks as if the field flux will not be cutting across the conductors, but such is not the case. It will still be cutting across them but at a slower speed because there is always a "slip" between the rotating magnetic field and the rotating element or secondary, or in other words the field moves a little faster than the rotor bars.

The primary or field windings of an induction motor are arranged and connected for a given number of pairs of poles, one north and one south. Any magnetic pole makes one complete revolution in the field structure in as many cycles as there are pairs of poles. If (f) represents the frequency in cycles per second, and (N) the number of pairs of poles, the number of revolutions of the magnetic poles around the field structure, per second, will be (f) divided by (N) or if the windings were arranged so as to have four poles, or two pairs of poles, and the frequency of the circuit was 60, then the number of revolutions of a magnetic pole per second would be 60 divided by 2 or 30. Then to get the revolutions per minute we must multiply by 60. We would then have 60×60 divided by 2 which equals 1800 r.p.m. of the magnetic field.

If the rotor, or secondary, of an induction motor could rotate in step with or at the same speed as the field, we would have what is known as synchronous speed. But due to the fact that the field must rotate faster than the armature in order that the armature conductors may be cut by the field flux, the rotor must lag a little behind the field. Now one thing to notice is that when the armature is stationary, the flux is cutting across the bars at a high rate of speed and generating in them a higher voltage than after the armature has come up to speed. This voltage forces a heavy current through the squirrel cage winding and produces a good twisting effort or torque to bring it up to speed. If the rotor should come up to a synchronous speed, the field flux being at the same speed as the squirrel cage conductors, there would be no voltage generated in them, no current would flow and we would get no torque and then it is reasonable to say that the rotor bars would slow down until they were cut across by the flux and a sufficient voltage was generated in them to force enough current to flow through, and produce a torque to carry the load. It can be seen then that with an increase of load on an induction motor, the speed is decreased till the torque exerted by the increased current in the rotor is strong enough to carry the load.

Meaning of "Slip"

The difference between the speed of the rotating magnetic field and the rotor is called the "slip" and is generally stated in per cent of synchronous speed. As stated before, the synchronous speed of a four pole machine is 60 times frequency divided by the number of pairs of poles, which equals the r.p.m., or if the frequency is 60 and we have four poles or two pairs of poles, then $60 \times 60 \div 2 = 1800$ r.p.m. If the speed of the rotor was only 1710 r.p.m., then the slip as stated in per cent would be

$$\frac{1800 - 1710}{1800} \times 100 = 5 \text{ per cent.}$$

The full load slip of commercial induction motors for moderate service ranges from 8 per cent in small motors to 2 per cent in motors of 100 hp. and over. As the torque must be sufficient to cause the secondary to rotate and the torque depends on the amount of current in the secondary conductors, and this depends on the speed at which we cut lines of force, then it can be seen that the

slip will automatically adjust itself according to the torque required. If the load increases, the slip increases, or if the load decreases the slip decreases, till the slip at no load is very small, meaning that the rotor and magnetic field will rotate at nearly the same speed. When a conductor on the rotor has slipped from under a rotating north pole to a position under a rotating south pole, the voltage generated in it is also reversed but as with d.c. motors, when we reverse the armature current we reverse rotation, reverse field current (or polarity) and we reverse rotation, but if we reverse armature and field at the same time we still have the same rotation, so when these conductors slip back from one pole to another they also have current flow opposite in them due to the reversed voltage generated and the field being also of another polarity we still obtain the same rotation. Now when this voltage in the conductors reverses twice, or when the conductor slips from under a south pole, a north pole and on under the next south pole, we have generated in it one cycle of alternating voltage and have a frequency of one for our alternating current in the rotor or squirrel cage winding. When we first started to rotate we had a high slip or in other words the conductors were slipping and lagging behind the rotating field quite fast. At the start we had a high frequency or the same as our a.c. line frequency, till the slip began decreasing as the rotor came up to speed. Then the nearer to synchronous speed we came the slower the conductors slipped from pole to pole and the lower the frequency became in the rotor, till at synchronous speed, if such were possible, we would have no frequency at all or no current flow in the secondary. If we increase the load the slip increases also. Then we would have conductors slipping from pole to pole faster and the frequency of the secondary would increase.

Reaction Between Rotor and Stator Currents

It is fairly well understood that ohmic resistance, self-induction, and mutual induction, the latter two being more pronounced in a.c. work and generally called inductive reactance, all tend to hinder the free flow of alternating current. These three things taken into consideration, we can give a common name to all three which will be, as used in nearly all cases, "impedance." This impedance is proportional to the frequency. It can be seen then that as the rotor attains a high speed, rotating almost in step with the rotating field it will have a very low impedance in comparison with what it had at the start. At the start we had a high voltage generated in the squirrel cage, but due to the high frequency we will not get as high current as might be expected. As the motor comes up to speed the frequency in the squirrel cage is decreasing, and we still have sufficient voltage generated in the squirrel cage winding to force considerable current to flow through it. With a decrease of frequency the impedance also decreases, until at near synchronous speed we have very little impedance. The current through the secondary winding determined to a great extent the torque of the motor. From the foregoing it can be seen that we will have more torque after the rotor has attained a sufficient speed to decrease the frequency of secondary current, and at the same time the impedance of the squirrel cage, or secondary. In reality a good motor of this type will develop at the start about 175 per cent of full load torque. Then as the frequency and impedance of the rotor is decreased, it increases in torque until at about 85 per cent speed it will develop nearly five times full load torque. Then the torque drops until at full speed or around 97 per cent synchronous speed, we are developing full load troque. It can be seen then that with an excessive load thrown on the motor, the speed will drop, but as the speed drops the torque will increase due to the higher voltage generated in the secondary. When we increase the load we also have an increased current in the rotor. This increase of current also builds up a stronger magnetic flux which is the same as armature reaction in d.c. motors. This armature reaction always tends to neutralize a portion of the field flux. The field flux which is produced by the alternating current through the stator winding, is the cause of inductive reactance in the a.c. circuit. It can be seen then that by increasing the load on the motor we increase the current through the secondary which builds up a flux and neutralizes part of the inductive reactance of the primary and, by neutralizing part of the reactance, we allow more current to flow in the primary windings. The more inductive reactance in a circuit, the lower will be the power factor of that circuit. Therefore, if we neutralize part of this reactance by increasing the load it can be understood that we also increase the power factor of that circuit.

It is always more economical not only for first cost, but also for power factor, to have the induction motors fully loaded, and not have a lot of extra, high inductive fields around the plant. This also holds true for transformers.

N. Y. Edison Co. Orders 132 kv. Pirelli Underground Cable

AS THE RESULT of an order which has just been given by The New York Edison Company to the General Electric Co., of Schenectady, an underground cable line which will be operated at 132,000 v., or twice the pressure of the most powerful underground cable line now used commercially anywhere in the world, will be installed in the Bronx within the next year. This new line, costing in the neighborhood of two and a half million dollars, will tie together the generating stations of The New York Edison Co. and its allied companies and at the same time it will make available 120,000 additional horsepower to meet the ever-growing demand for power in this area.

Until two years ago, the highest pressures used in underground cables in America did not exceed 33,000 v. In that year The New York Edison Co. and its allied companies placed in service a new type of cable operating at 45,000 v. Recently another company installed a 66,000 v. underground cable which is at present the most powerful line of its kind used commercially.

In place of a complicated, overhead transmission line, the new cable, which, with its insulation will be only 3 in. in diameter, will be placed in concrete ducts 4 or 5 ft. below the surface of the ground. The cable to be used for this purpose is known as the Pirelli type, patent rights on which were recently secured by the General Electric Co. from the internationally famous Italian electrical firm of that name, and embodies in its construction the latest inventions in design of underground cables for high pressures. Because of the pioneering character of this installation and the methods used to overcome the engineering difficulties which the new problem presents, the installation of this cable will be watched with the greatest interest by electric public utilities all over the country.

Thermal Gain Results from Resuperheating

HEAT CONSUMPTION OF A STEAM TURBINE MAY BE DECREASED 6 TO 7 PER CENT AS A RESULT OF RESUPERHEATING THE STEAM.

BY W. E. BLOWNEY AND G. B. WARREN

IT HAS BEEN recognized for a long time that whatever gain would result from resuperheating was in the main part due to the increase in the steam-turbine efficiency resulting from the greater superheat and reduced moisture content of the steam in the turbine rather than to the thermodynamic improvement of the heat cycle.

Data relative to the gain in turbine efficiency with increased initial superheat are, on the whole, not as complete as might be desired, particularly on large turbines, since it is difficult to vary the initial superheat over a satisfactory range in the average power station. In the main part, it has been necessary to base the present series of calculations upon tests on turbines of from 2500 to 10,000 kw. capacity but complete tests are available at low initial pressures and fairly complete tests are available at moderately high pressures at these capacities.

Modern turbines are made up of a number of individual stages, each stage taking a part of the pressure drop and thus a part of the heat or energy drop. It would be thought at first that the efficiency of the complete turbine would be the weighted average of the individual stage efficiencies. This, however, is not quite true. Since each stage is less than 100 per cent efficient, a certain amount of energy is lost in each stage and is thus reconverted into heat which is used in "reheating" the steam. This reheating of the steam in each stage thus makes a greater amount of energy available in the succeeding stages, since it increases the entropy. Therefore, the summation of the adiabatic energy drops of each stage is always greater than the adiabatic energy drop over the entire machine.

There is reason to believe from data available that there is practically no change in the individual turbine stage efficiency with increase in the average superheat of the steam in the stage. The change in the average stage efficiency with superheat must then be due to the change in the stage efficiency with change in the moisture content of the stages in the moisture region. The method of analysis, therefore, to find the average correction to apply to the stage efficiency is to correct for the moisture content in the stage on the assumption that the expansion takes place in thermal equilibrium, and that the reduced efficiency with increased moisture content is due to the mechanical effect of the moisture in the steam. This method then involves no assumption regarding the probable degree of super-saturation of the steam during the expansion.

In general, the higher the pressure in a stage the lower will be its efficiency due to the necessarily smaller nozzles and buckets and to the higher rotation and packing losses. Inasmuch as the stage efficiency is largely a matter of design, two assumptions must be made regarding its variation with pressure: (1) That the dry-stage efficiency decreased in a certain manner as the pressure increased and (2) That the dry-stage efficiency was constant throughout the turbine.

Due to the fact that the curves given in this paper do not include last-stage leaving losses, bearing losses, high- or low-pressure packing losses, or generator losses, all thermal efficiency curves should be considered as being relative and not absolute in value.

Figures 1 and 2 show the order of magnitude of the percentage gain in thermal efficiency due to resuperheat-

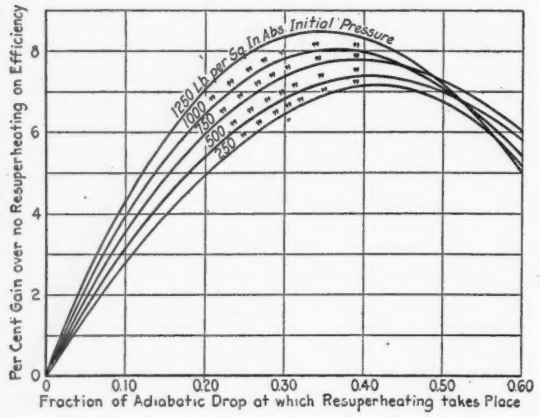


FIG. 1. PER CENT GAIN IN THERMAL EFFICIENCY OF A TURBINE DUE TO RESUPERHEATING WITH VARIABLE STAGE EFFICIENCY

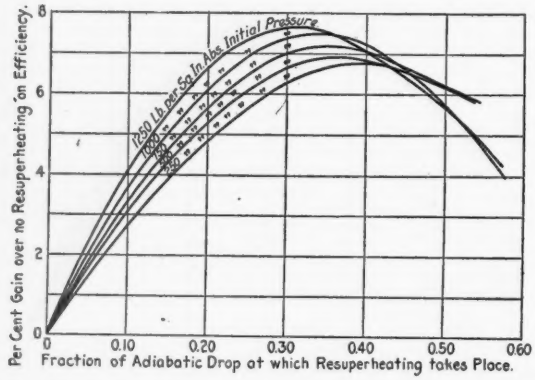


FIG. 2. PER CENT GAIN IN THERMAL EFFICIENCY OF A TURBINE DUE TO RESUPERHEATING WITH CONSTANT STAGE EFFICIENCY

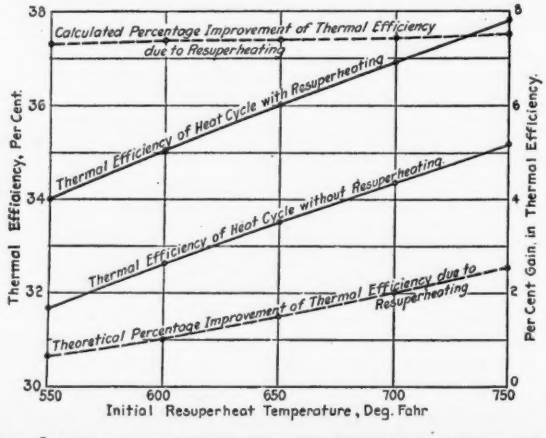


FIG. 3. PER CENT GAIN DUE TO RESUPERHEATING AS A FUNCTION OF INITIAL AND RESUPERHEATING TEMPERATURE

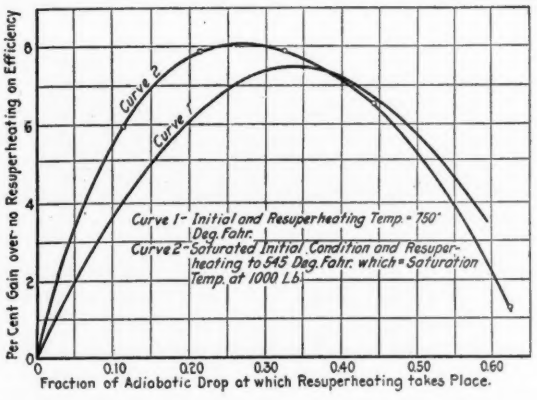

Per Cent Gain over no Resuperheating on Efficiency
Curve 2
Curve 1
Curve 1- Initial and Resuperheating Temp. = 750° Deg. Fahr.
Curve 2- Saturated Initial Condition and Resuperheating to 545 Deg. Fahr. which = Saturation Temp. at 1000 Lb.
Fraction of Adiabatic Drop at which Resuperheating takes Place.

FIG. 4. GAIN DUE TO RESUPERHEATING WITH TWO DIFFERENT INITIAL TEMPERATURES AT 1000 LB. ABS. INITIAL PRES. AND 1 IN HG. ABS. BACK PRESSURE

ing. No account has been taken of the pressure drop in the resuperheater and connected piping, as this will, of course, depend upon the particular design. Such drop will probably reduce the gain by ½ to ¾ of one per cent.

Gain Is Greater at Initial Pressures

It is interesting to note that the gain, considering the change in a turbine efficiency, is greater at the higher initial pressures, whereas the theoretical gain, considering the heat cycle alone, is lower at the higher pressures. This is due to the fact that a greater portion of the turbine is operating in the moisture region with the high initial pressures and so is susceptible of greater improvement.

It should also be noted that the best point for resuperheating comes at approximately one-fifth to one-sixth of the initial pressure. This gives resuperheating pressures for initial pressures of 500 lb. per sq. in. and more, which do not require resuperheating piping of excessive size. The greater gain shown by the assumption that the dry-stage efficiency decreased with increasing pressures in the stage is due to the fact that the gain in turbine efficiency from superheating is greatest in the low-pressure end where the efficiency is the highest under the variable efficiency assumption. This results in a greater improvement than on the assumption of a constant stage efficiency. The variable stage efficiency is the more probable condition, considering the design of present-day machines.

In order to determine the effect of different initial and resuperheat temperatures upon the gain in thermal efficiency, a set of calculations was made on the assumption that the initial and resuperheat temperatures were varied from 750 deg. F. to 550 deg. F. total temperature. The initial and resuperheat temperatures were assumed equal in all calculations, and the point of resuperheating was taken at a ratio of 0.355 of the adiabatic drop for the 750 deg. F. condition with 1000 lb. per sq. in. absolute initial pressure. This put the resuperheating pressure at 150 lb. per sq. in., absolute. The results of this calculation are shown on Fig. 3, and show that the percentage gain in thermal efficiency is approximately constant at this resuperheating pressure irrespective of the maximum temperature of the cycle so long as the resuperheating temperature equals the initial temperature. This is in marked contrast to the theoretical gain with increased initial and reheat temperature, as also shown on Fig. 3.

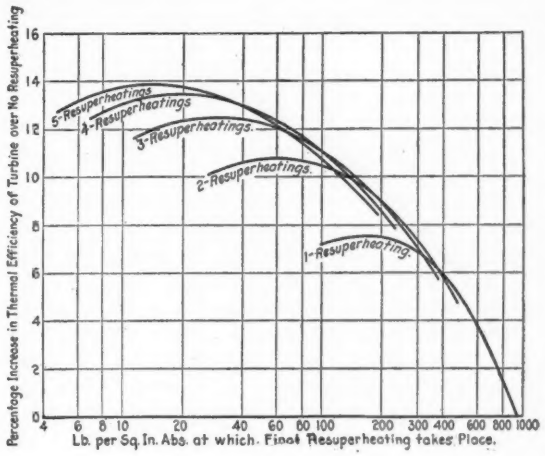


FIG. 5. PROBABLE ACTUAL COMPARATIVE GAIN IN THERMAL EFFICIENCY DUE TO USING ONE OR MORE STAGES OF RESUPERHEATING

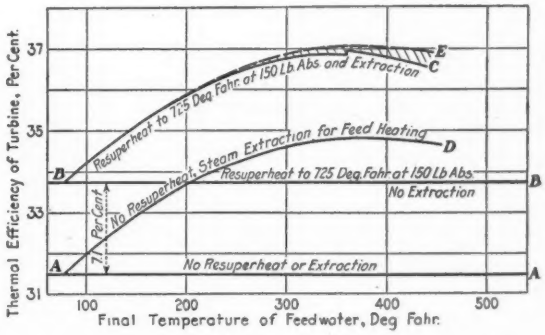

Thermal Efficiency of Turbine, Per Cent.
Resuperheat to 725 Deg. Fahr. at 150 Lb. Abs. and Extraction
Resuperheat & Steam Extraction for Feed Heating
Resuperheat to 725 Deg. Fahr. at 150 Lb. Abs.
No Extraction
No Resuperheat or Extraction
Final Temperature of Feedwater, Deg. Fahr.

FIG. 6. COMPARATIVE THERMAL EFFICIENCIES WITHOUT RESUPERHEATING AND WITH STEAM EXTRACTION IN THREE STEPS AND OF TURBINES WITH BOTH RESUPERHEATING AND EXTRACTION

Figure 4 shows comparative curves giving the per cent gain in thermal efficiency when reheating or resuperheating at various fractions of the adiabatic drop with initial temperatures and resuperheat temperatures of 750 deg. F. in one case and in the other case equal to the temperature of saturated steam at the 1000 lb. per sq. in. absolute initial pressure. These curves indicate that the best point for resuperheating is not necessarily the point at which the steam in the high-pressure turbine loses its superheat, as is quite commonly believed.

Resuperheating More Than Once

If it is advantageous to resuperheat once it immediately becomes apparent that it might be more advantageous to resuperheat more than once. The complication of such an installation would of course be considerable, but the first thing is to find out the probable gain which might result in order to determine whether such multiple resuperheating would pay economically considering the increased complication and investment involved. If it is assumed that the drop in steam pressure in the resuperheaters and connected piping can be made so low as to reduce the available heat only one-half of one per cent for each resuperheating, this is somewhat lower than present practice, the net gains resulting from one or more resuperheatings will be as shown in Fig. 5. It can then be seen that the gain in going

from two to three stages of resuperheating becomes so slight as to offer slight inducement to accept the increased complication and expense involved. The increase in efficiency resulting from two resuperheatings as compared to one might, however, warrant such an installation in the case of very large high-pressure base-load units.

There appears to be no practical difficulty in the way of extracting superheated steam from a turbine for use in a closed or open heater for feed heating purposes. It has been thought of value, therefore, to investigate whether both the resuperheating and regenerative cycles could be used together, so as to obtain the sum of the two gains of the cycles when used separately. It has been found that under the conditions which would probably obtain, the total gain in thermal efficiency of the combination is equal to practically 95 per cent of the sum of the gains in efficiency when used separately. This is on account of the small proportion of the heat in the extracted steam which is due to the superheat.

Figure 6 shows a resuperheating and a non-resuperheating cycle with steam extracted at three equally spaced points for heating the feed water in both cases. The curves were made so as to show the gain in each case when heating the feed water to different temperatures. The feed heating calculations were made on an ideal basis assuming no temperature drop, no pressure drop and contra-flow conditions in the heaters so that the drip from each heater left the heater at the temperature of the incoming feed water. The drip was drained into the next lower heater in each case.

The information and data given herewith were obtained from a paper "The Increase in Thermal Efficiency Due to Resuperheating in Steam Turbines," presented before the annual meeting of the A. S. M. E.

Electric Refrigeration Interests Central Stations

PROGRESS IN DESIGN OF SMALL ELECTRIC REFRIGERATING UNITS FOR THE HOME AND FOR SMALL COMMERCIAL APPLICATIONS IS REPORTED TO N. E. L. A.

IN THE FIELD of refrigeration, one of the most recent developments of interest to central station engineers is that of the electric refrigerating machine for use in the home and for small commercial applications such as water coolers and soda fountains. During the past year, progress in standardization and refinements in existing types of equipment have been made by manufacturers who have been longest in the field. Many new machines have been announced, but few have arrived; there have been many new applications, but few new principles involved. Quantity production methods have resulted in a reduction of prices on the part of at least two manufacturers, who are now producing small domestic units which sell at about $250.

Service records indicate an improvement in performance of electrical equipment of these small refrigerating units as compared with the records of two or three years ago. Central stations are interested in this subject insofar as performance of such equipment affects continuity of service, as well as in the starting current, efficiency and power factor of the small motors used. Thermostat performance has been much improved and is, in general, commercially satisfactory. Since the preserving of perishable foodstuffs is a critical service, and central station engaged in promoting refrigeration should make certain that a service department is established with sufficient trained personnel to give proper attention to service calls day or night.

These are among the significant points brought out in the recent report of the Electric Refrigeration Committee of the Commercial National Section of the N.E.L.A., presented at the 48th convention at San Francisco, Cal., June 15 to 19, 1925. The various subcommittees of this committee have obtained many interesting data, which are incorporated in the report and are summarized below.

TEMPERATURES BELOW 45 DEG. PREVENT SPOILING OF FOOD

Prevention of the spoiling of food is one of the chief objects of refrigeration. This is accomplished by preventing the growth of microbes, which cause this decomposition. The growth of microbes is prevented at temperatures below 45 deg. F., although they are not destroyed by cold and will immediately become active and multiply again when the temperature is increased. It can be seen, therefore, that a refrigerator which is not kept at refrigeration temperature furnishes food, humidity, darkness and still air—just the conditions needed for bacterial growth.

Refrigeration is the process of removing heat from a confined space in order to lower its temperature below that of its surroundings. This confined space is located in a refrigerator, and its temperature may be kept at a low point by several types of refrigerating machines. Most of

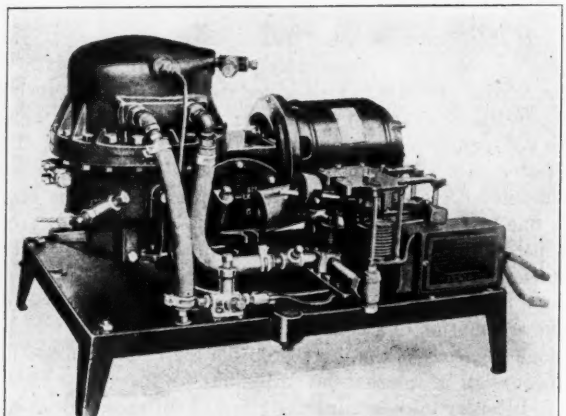


FIG. 1. SULPHUR DIOXIDE IS THE REFRIGERANT IN THIS WATER COOLED UNIT

these employ the boiling of a liquid at temperatures below refrigeration. It has been found desirable to use liquids that boil naturally at or near refrigeration temperature and, since there are no such liquids existing in nature it is necessary to manufacture them from gas—ammonia, carbon dioxide, sulphur dioxide, ethyl and methyl chloride being most commonly used—by compressing and cooling them. Another principle sometimes employed is that a compressed gas, allowed to expand against resistance, will give up some of its energy to the moving system, thus losing heat. The above principles are applied in mechanical refrigeration in several systems: compression, absorption, vacuum, air and vapair systems.

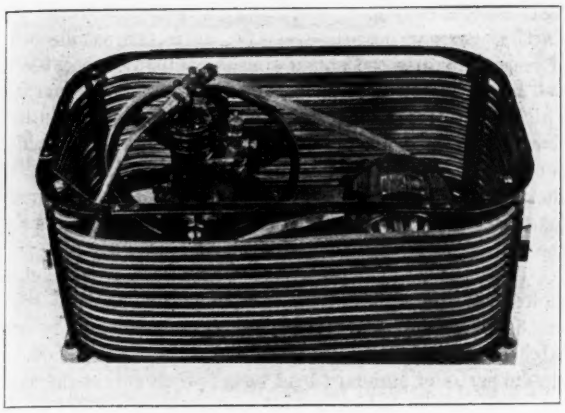


FIG. 2. RECTANGULAR STAND OF COPPER CONDENSING COILS ENCLOSES THIS COMPRESSOR UNIT

In preparing the data and description of the various types of small refrigeration machines the committee has endeavored to cover the field as thoroughly as possible. To this end a representative has visited many manufacturing centers and has also made a comprehensive trip through the Middle West calling on central stations and manufacturers. Questionnaires were sent to those manufacturers and prospective manufacturers not visited and further information obtained from other committee members.

Frigidaire household refrigerating machines are produced in two general types; namely, water-cooled and air-cooled units. Both are of the compression variety and emplay sulphur dioxide as a refrigerant. The water cooled unit is made up of a two cylinder compressor connected by gears, which run in oil, to a ¼ hp. motor. Ice trays permit the freezing of 24, 36, 48 and 72 ice cubes, depending on the size of the cooling unit. Freezing time varies from 3 to 6 hr. Temperature control is accomplished by means of the action of a distending bellows connected to the low pressure side of the system. The Frigidaire air-cooled unit is similar in many respects to the water-cooled, the same cooling units being used with both type of machines.

Kelvinator refrigerating units are of the compression type and use sulphur dioxide as the refrigerant. A vertical, enclosed, reciprocating type compressor is used, driven by a ¼ hp. motor. Ice trays are inserted in a hollow section of the cooling tank to permit the freezing of ice. The freezing time is from 1½ to 6 or 7 hr. A thermostat consisting of a switch and siphon bellows controls the action of the motor.

The Servel machine is of the compression, air-cooled type, using methyl chloride as a refrigerant. The mechanical element consists of a two-cylinder air-cooled compressor driven by means of a belt by a ¼ hp. motor. The cooling tank is made of copper containing an alcohol solution. A series of coils mounted in this tank evaporates the refrigerant and produces the cooling effect. Temperature control is accomplished by means of the action of a distending bellows connected on the low pressure side of the system.

In the Copeland Refrigerating Machine, the compression unit consists of a 1/6 hp., single phase motor, belt driven compressor, and an air cooled elliptically shaped stand of condensing coils. Isobutane is used as a refrigerant. The refrigerator temperature is controlled by means of a sylphon bellows type of thermostat inserted in the top of the brine tank.

The Electrice Household Machine is of the compression type, using sulphur dioxide as a refrigerant, and consists of a 1/6 hp. motor, direct connected to a 1750 r.p.m. pump, which acts as a compressor. The temperature of the refrigerator is controlled by a thermostat set in the food compartment of the box.

Using sulphur dioxide as a refrigerant, the Electro-Kold Refrigerating Machine consists of a single cylinder vertical compressor, driven by belt from a motor. Temperature control is by means of a mercury tilting thermostat, located on the top of the brine tank.

The Fowler machine is of the compression type and consists of a four cylinder vertical compressor, direct driven at 900 r.p.m. by a ¼ hp. motor. Temperature control is accomplished by means of a sylphon type thermostat subjected to the brine temperature in the cooling tank.

The Frostic is an air-cooled compression machine using a two cylinder horizontal compressor, driven from spur gears, by a ¼ hp. motor. Sulphur dioxide is the refrigerant. Temperature control is accomplished by the means of a pressure type switch connected on the suction line in such a way as to cut the motor on or off between predetermined points of pressure. Frostic machines can either be installed as self contained units, or applied to any existing cabinet.

The Keokuk Refrigerating Machine consists of a two cylinder, vertical, air cooled compressor, driven by means of a ¼ hp. motor through the medium of spiral gears running in oil.

Lipman machines are manufactured in a number of sizes, varying from a ¼ hp. belt driven household machine to a 15 T. commercial machine. The household machine consists of a single cylinder vertical compressor, driven by means of a motor through a belt, the motor and compression units being mounted on a cast iron base. Ammonia is the refrigerant. An automatic expansion valve admits the condensed liquid ammonia to direct expansion coils located in the cooling chamber of the cabinet. Temperature control is accomplished by means of a mercury tube tilting thermostat in the food compartment of the cabinet.

The Odin machine is a self contained unit, and consists of a well-insulated cabinet with the mechanical equipment occupying a space the entire height of the box at one end. The Polaris Refrigerating Machine is of the single cylinder compression type and uses sulphur dioxide as a refrigerant. The mechanical unit is integral with the

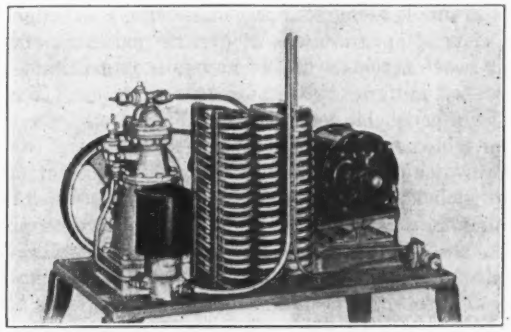


FIG. 3. PRESSURE REGULATING CONTROL OF AIR-COOLED UNIT, EMPLOYING METHYL CHLORIDE AS A REFRIGERANT, IS SHOWN IN FRONT OF COMPRESSOR

cabinet and is manufactured as one complete unit in various sizes of steel, cork lined cabinets. The Savage Refrigerating Machine employs an Archimedes screw containing mercury which compresses either ethyl chloride or butane, the two refrigerants used, through virtue of the centrifugal force exerted on the mercury while the machine is in operation. The Valley Refrigerating Machine is of the single cylinder, compression type, and uses sulphur dioxide as a refrigerant.

Committee Tests Several Types of Electric Units

With the idea of obtaining data which will be of use to the industry and also to determine methods of test which can be used by those interested in investigating any particular equipment, the subcommittee on tests was formed. The work of the subcommittee is being carried on by the testing laboratories of the following companies: Public Service Electric & Gas Co., Philadelphia Electric Co., New York Edison Co., Brooklyn Edison Co., Consolidated Gas, Electric Light and Power Co., of Baltimore.

TABLE I. TESTS OF SEPARATE UNITS INSTALLED IN 13.3 CU. FT. CABINET. STANDARD LOAD, 8 B.T.U. PER HR. PER CU. FT.

Refrigerator	Room Temp. Deg. F.	Ref. Temp. Deg. F.	Temp. Diff. Deg. F.	Kw.-hr. per 24 Hr.	"K"	Number Machine Operations per 24 Hr.	Per Cent Time in Operation
90 Deg. Room (Nominal)							
S-1	90	54	36	2.78	5.81	44	37
S-2	90	57	33	3.36	7.66	14	50
S-3	91	56	35	4.56	9.95	4	68
S-4	91	60	31	4.05	9.98	105	49
80 Deg. Room (Nominal)							
S-1	80	50	30	2.40	6.01	42	29
S-2	80	53	27	2.92	8.13	13	42
S-3	80	53	27	3.18	9.00	6	47
S-4	82	54	28	3.95	10.9	68	42
70 Deg. Room (Nominal)							
S-1	71	47	24	2.17	6.80	39	27
S-2	70	50	20	2.50	9.39	12	40
S-3	70	50	20	2.74	10.5	7	40
S-4	71	52	19	3.33	13.4	57	33

Note: "K" equals watt hours per 24 hours per cubic foot per degree difference in temperature.

Some time was spent on getting data on ice performance in an ice cabinet of 13.3 total cu. ft. capacity. Tests of ten types of refrigerating units have been made. The problem is not as simple as might appear on superficial examination. This class of apparatus, as at present marketed, aims to fulfill two functions: (1) to maintain at a suitable and reasonably uniform temperature a compartment for the storage of perishable food; (2) to supply at all times cube-ice for table use.

Operation of the apparatus is intended to be automatic, but it is obvious that conditions arise at times which make the simultaneous carrying on of the two functions almost impossible. In designing the automatic control a compromise is therefore necessary with the idea of obtaining as good an over-all performance as possible.

Improvement in the characteristics of motors for this class of equipment has received some attention from the subcommittee and the matter will be carried further in the immediate future. From all standpoints it is desirable that the efficiency and power factor be increased and the starting current decreased, as far as is compatible with of reasonable price. Central station companies, because of the large amount of household refrigerating apparatus which will be connected to their lines in the near future, should favor that machine, other things being equal, which is equipped with the most satisfactory type of motor. The committee is making efforts to bring together the motor manufacturers and electric refrigerator manufacturers to the end of improving this situation.

Tests are run on each sample machine or cabinet at at least three different room temperatures with "no load" on the cabinet; i. e., the doors are kept closed and the door latches are sealed throughout the 24 hr. test period. A second series of standard load tests is then run at the same temperatures as before, a load amounting to 8 B.t.u. per hr. per cu. ft. of cabinet contents, being introduced electrically by an immersion heater in a pan of oil placed on the floor of the food compartment. The door latches are sealed as before. These two series of tests are conducted in the same way whether cabinets are cooled with ice or electrically refrigerated. When ice is used the amount is determined by weighing the "drip" collected in a covered pan during the test period. The cabinet is iced before beginning the test and is not re-iced during the test. Results of some of these tests are shown in Tables I and II.

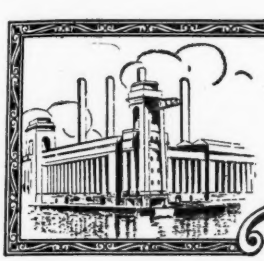
TABLE II. TESTS OF FOUR CABINETS, USING ICE IN PLACE OF ELECTRIC UNIT. STANDARD LOAD, 8 B.T.U. PER HR. PER CU. FT. HR. PER CU. FT.

Cabinet	Inside Cubic Contents Cu. Ft.	Room Temp. Deg. F.	Ref. Temp. Deg. F.	Temp. Diff. Deg. F.	Lb. Ice per 24 Hr.	"K"
90 Deg. Room (Nominal)						
1-1	9.70	90	59	31	39.6	0.132
1-2	15.90	90	62	28	59.3	0.133
1-3	13.30	90	61	29	49.0	0.127
1-4	9.76	--	--	--	----	----
80 Deg. Room (Nominal)						
1-1	9.70	80	55	25	35.8	0.147
1-2	15.90	80	57	23	53.5	0.145
1-3	13.30	82	56	26	44.5	0.129
1-4	9.76	--	--	--	----	----
70 Deg. Room (Nominal)						
1-1	9.70	71	51	20	32.5	0.168
1-2	15.90	72	54	18	45.9	0.160
1-3	13.30	74	54	20	39.5	0.148
1-4	9.76	--	--	--	----	----

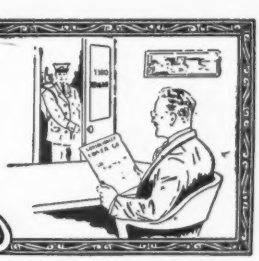
"K" = Lb. ice per 24 hr. per cu. ft. per deg. difference in temperature.

In making comparisons of the performance of different equipments it is necessary to consider in each case the size of the cabinet. To facilitate such comparisons we have introduced a unit figure "K," which with electrical operation is watt-hours per 24 hr. per cu. ft. per deg. difference in temperature and when operating with ice is pounds of ice per 24 hr. per cu. ft. per deg. difference in temperature.

Another section of this report, taking up the subject of comparative costs of refrigerating with small electric units and with ice, will be discussed at greater length in an early issue.



LETTERS DIRECT FROM THE PLANT



Money May Be Saved by Judicious Spending

THE PURCHASE of the most efficient equipment for performing a given task, even if the first cost is high, is without doubt the best policy to follow and in most cases will show a large reduction and saving in operating costs even after deducting the annual interest charges on the money invested and allowing for depreciation.

This applies more forcibly to power producing equipment than any other department in industry. Take, for instance, a power plant in a paper mill in this city having a 600 kw. turbine generating electric power for a three machine mill. The paper machines are motor driven and require a total of 180 kw. and run 24 hr. per day. The boilers are of the water-tube type, stoker fired, and well suited to the plant, operating at 185 lb. pressure and 100 deg. of superheat. This plant burns 27 T. of coal per day and the hourly consumption of 1⅛ T. is used to supply steam to the turbine and pumps; also to supply steam to the machine room for the purpose of drying paper. The turbine uses 2 lb. of coal per kw-hr. generated or 1200 lb. per hr. and is loaded to full capacity most of the time. The machine room, which takes large quantities of live steam at 10 lb. pressure through a reducing valve uses about 1000 lb. of coal per hr. It is not possible to use any exhaust steam from the turbine in the machine room, since the turbine is not designed for that purpose. At the time of installing the turbine, the mill was considered modern and efficient in every way, but I can prove that several thousand dollars can be saved by installing another engine to operate with the turbine and take part of the load now carried by the turbine which has practically no reserve capacity under present conditions.

Now, since 1000 lb. of coal per hr. are used to furnish steam for drying paper in the machine room and the boiler evaporates 9 lb. of water per lb. of coal, it follows that 9000 lb. of steam per hr. are used for process work without generating any power from this steam. It is reduced in pressure from 185 lb. to 10 lb. throught a reducing valve. Now if this 9000 lb. of steam were passed through an efficient engine and exhausted at 10 lb. back pressure to the paper machines, at least 300 kw. could be generated. A uniflow engine taking steam at 185 lb. pressure and expanding down to 10 lb. could easily show a water rate as low as 30 lb. per kw-hr. Then the turbine would only have to generate 300 kw., which means that the coal consumption of the turbine (which is 1200 lb. per hr. when generating 600 kw.) would practically be cut in half and a saving of 600 lb. of coal per hr. made possible.

Coal costs this company $7.00 per short ton and at this price the annual amount of money saved would be

$$\frac{600}{2000} \times 24 \times 300 \times 7.00 = \$15{,}120 \text{ per year.}$$

(Plant runs 300 days per year, 24 hr. per day.) Of course, this coal saving would not be all velvet, since we must figure 5.5 per cent interest on the cost of the new engine and allow a depreciation charge of 5 per cent, also 1 per cent charge for maintenance. A uniflow engine of 300 kw. capacity can be purchased for $70.00 per kw. and the yearly capital charges will be 11.5 per cent of $21,000, the latter figure being the total cost of the engine.

So we must deduct $2410.00 (11.5 per cent × 21,000) from the coal saving of $15,120, which gives us $12,710 as the net saving per year due to improved equipment. This is equivalent to a dividend of 60 per cent on the money invested and no company ought show any hesitation in purchasing equipment that will give such a high return on their investment.

In spite of these facts, this particular company has seriously considered the proposition of buying their power in order to reduce the coal bill. But the lowest rate for power in this locality is 1¼ cents per kw-hr. and the cost of power generated by a uniflow engine running under the conditions specified, that is, exhausting into the paper machines and drying paper with exhaust steam instead of using live steam, will be less than half a cent per kilowatt-hour.

Steam passed through the engine at 185 lb. pressure contains only about 7 per cent more heat than the exhaust steam at 10 lb. pressure which is used in the paper machine. Also the exhaust will contain about 4 per cent water, which must be extracted. Therefore, only a total of 11 per cent of the coal required to generate this 900 lb. of steam can be charged to the operation of the engine. This 11 per cent of 1000 lb. amounts to 110 lb. of coal per hr. and the balance of 89 per cent must be charged to the driers, since it would be used anyway, even if no engine was installed.

We can generate 300 kw. with 110 lb. of coal, which gives us a fuel charge of only $0.0013 per kw. Since,

$$\frac{110}{300} \times \frac{7.00}{2000} = 0.0013.$$

Now, since the plant operates 7200 hr. per yr., the capital charge of $2410 amounts to 33 cents per hr. and generating 300 kw. gives the capital cost per kw-hr. as $\frac{33}{300}$ or $0.0011. The total cost of generating with this engine is actually less than a quarter of a cent per kw-hr. (0.0013 × 0.0011 = 0.0024) and yet hundreds of paper mills and other industrial plants have overlooked this great possibility when, trying to reduce their power costs. If this plan were aggressively pushed by manufacturers of power equipment, the effect on production costs in many industries would be quite pronounced.

Holyoke, Mass. A. F. SHEEHAN.

American Made Bombs Are Satisfactory

In the June 1 issue, page 600, is an account of the new calorimetric bomb which is to be manufactured by M. Moureu at the College of France. This bomb will have a lining of gold, platinum, and copper, instead of the thick all-platinum lining in the former bomb.

We do not have to go to France for a successful bomb, when we are turning them out almost on a quantity production basis in this country.

Many disadvantages of a lined bomb for such calorimetric determinations as the heat content of coal, which of course represents the commonest use of a bomb, have long been known. Many different materials have been tried in the effort to find a lining which would resist the powerful corrosive action of the acids which are released when a powdered sample of coal is burned in an atmosphere of pure oxygen. A successful material was also required to stand a considerable amount of jarring and banging in a commercial laboratory.

The search for a suitable material took on an entirely different slant when Professor S. W. Parr of the University of Illinois developed an alloy which he called "Illium." Instead of using this alloy for a lining, he built the entire bomb from it, since it could be made into an almost flawless ingot and could be machined without great difficulty.

Exhaustive tests proved that Illium compares very favorably with the best lining materials in its resistance to acid corrosion, and of course the bomb would stand any amount of rough handling.

In 1919 and 1920, the writer used one of these bombs constantly as a part of the Parr Adiabatic Oxygen Bomb Calorimeter for determining the calorific value of coal samples. The results were perfectly satisfactory.

The bomb to be constructed by M. Moureu will unquestionably be very expensive and will probably be hailed as a great scientific achievement. But I seriously question whether the results that can be obtained with it will be any more reliable or accurate than with an Illium bomb.

North Glenside, Pa. W. J. Risley, Jr.

Caution Needed in Handling Ammonia Under High Pressure

In the issue of June 1, comments by W. F. Schaphorst on the incombustibility of ammonia and the probable reasons for a reported explosion, bring up several interesting points in the writer's experience which may be of interest to readers.

It would be of interest to know whether the compression or absorption system was used. Mr. Schaphorst states that the probable cause of the explosion was undersized safety valves on the ammonia receiver. The writer does not believe ammonia to be combustible in the full sense of the word and there is no doubt that the explosion was caused by sudden expansion of the gas under heat. Although this is the point which Mr. Schaphorst meant to emphasize, his reference to safety valves might lead some to believe that ammonia tanks or drums are equipped with safety valves. This is not the case, since all drums containing liquified ammonia are supposed to be made strong enough to withstand high pressures and, if the absorption system was used, it is unlikely that there would have been any safety valves. On the other hand, if the compression system was used, there would have been safety valves on the compressors or receivers but none on the drums.

In some types of absorption systems, the entire equipment will stand a pressure of 300 lb. but in those using high- and low-pressure jars, the low-pressure jars on the return side will not stand much pressure, while the anhydrous storage containers will probably withstand a pressure of 600 to 800 lb. before bursting. This may account for the terrific explosion and ensuing disabling of firemen by "cold smoke" referred to by Mr. Schaphorst.

Since ammonia drums must be moved about, it would be extremely dangerous to provide safety valves which might be broken off in handling. It is true that safety valves might prevent explosions due to expansion of the gas when heated but the escape of this gas might cause trouble even when the heat was not great enough to cause an explosion, since anhydrous ammonia, 100 per cent pure, is deadly if inhaled. The best means of safety should therefore be found in placing ammonia drums in cool, fire-proof vaults. Aqua ammonia, usually kept under 180 to 250 lb. pressure, is only 25 per cent pure and the fumes, while unpleasant, are not necessarily dangerous.

Due to its low temperature when first liberated, anhydrous ammonia gas is heavier than a given volume of air and will creep along the floor of a room in dense clouds of what appears white smoke which gave rise, no doubt, to the term "cold smoke." As the temperature increases, the ammonia gas will rise until the whole room is filled with fumes. As compared with air at the same temperature, ammonia gas is only about one-half as heavy.

At low temperature, ammonia escaping from leaks appears as smoky fumes and one needs only to get his hands in contact with this "smoke" to realize how cold it is. When tightening leaky stop-cocks or packing glands, it is always a wise precaution to turn a stream of water on the leak to absorb the gas as much as possible. This may save many frost bitten or frozen fingers.

When ammonia is liberated at a fire, it seems to unite with the smoke so that the heat of the latter is absorbed by the ammonia gas, leaving a cold smoke previously mentioned.

Gas masks with proper absorption canisters should be provided and always available wherever ammonia refrigeration systems are used.

Cambridge, Mass. R. A. Cultra.

Your Habits May Mean Profit or Loss

Recently I heard a minister state that habits, good or bad, are difficult to overcome. It is indeed regrettable that a lot of power plant owners could not have heard that stirring sermon.

Many plant owners or managers, in a large measure are responsible for some of the bad habits of their engineers or other employes and these men will often become as careless as their employer shows himself to be. An engineer should, and most generally does, have the interest of the plant at heart but will often become discouraged and fall into careless ways if the plant owner, especially one in smaller plants who does not employ a manager, fails to visit the plant and look things over regularly.

In many places a single boiler unit is operated only in the daytime and there is just one man to fill the job of both fireman and engineer. It would take only 15 min.

each day for an owner to look things over and the time so spent would be invaluable in getting the good will and co-operation of his employes. He would soon form an exemplary habit of critical but fair-minded inspection and the engineer or fireman would form the habit of tidiness in both the engine and boiler room.

When a formerly careless operator gets into the habit of improving things it may often be traced to interest shown by the plant owner. When a plant owner or manager fails to provide suitable tools or equipment for making necessary repairs, fails to encourage his men to read power plant magazines or textbooks and shows by his actions that he has little interest in his own plant beyond merely keeping it operating, then he has formed a lot of profit losing habits and by his example is teaching his men to be as thoughtless as himself.

Toronto, Can. JAMES E. NOBLE.

Removal of Crosshead Shoe Made Easier

ON OUR 26 by 48-in. heavy duty engine, the crosshead shoes are secured by a stud in the end of the crosshead, with a nut on each side of the "ear" of the shoe. A clamp bolt, with a nut on the end, reaches through the shoe,

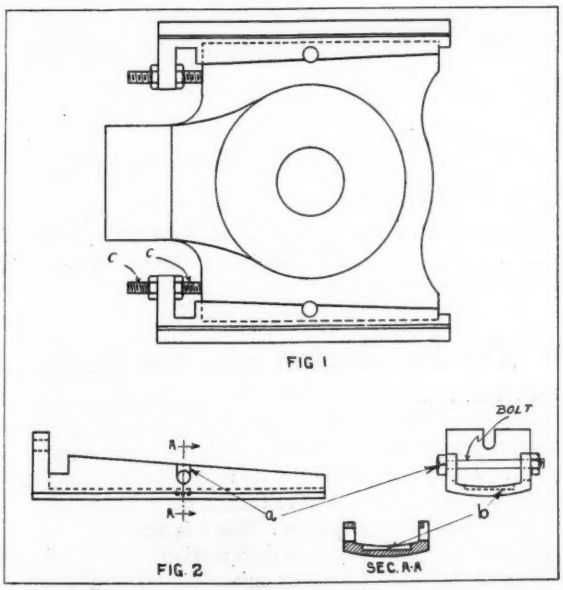


FIG. 1. WITH THIS CONSTRUCTION CONNECTING ROD MUST BE REMOVED TO GET SHOES OFF

FIG. 2. SLOTS A AND B ALLOW CLAMP BOLTS TO BE TILTED AND REMOVED EASILY

clamping it tightly. The take-up is of the wedge type, the crosshead and shoe being tapered as shown in Fig. 1.

Whenever we wished to remove a shoe, it was necessary to disconnect the connecting rod at the crosshead, because the clamp bolts could not be removed unless the crosshead was rolled somewhat in the guides. If it was not rolled, the clamp bolts would hit the sides of the bed before they could be removed. As shown in Fig. 2, we machined a slot a in the front side of each shoe, from the edge to the clamp bolt hole and cut a channel b about $\frac{5}{16}$ in. deep in the shoe. This enabled us to tilt the clamp bolt, while it was being removed enough to clear the engine frame and eliminated for all time the extra work of taking down the connecting rod at the crosshead when removing a shoe.

Burlington, Ia. TOM JONES.

Decreasing Steam Consumption of Soot Blowers

MUCH VALUABLE steam can be saved, when using mechanical soot blowers, by proportioning the amount of steam almost directly with the amount of heat absorbed by the tubes in the various passes. The first rows of tubes with which the gases and radiant heat come in contact absorb most of the heat, therefore they should have more attention than the tubes in the last passes which absorb much less.

If it is impractical to clean the last passes more quickly than the first passes because of the mechanical construction of the blower, it may be better to omit operating the blower in the last passes every time some blowing is done. It is better to confine one's efforts to cleaning the first passes. Thus the last passes may be blown once a day or even once a week, depending upon the kind of fuel or the overload. At the same time, it might be well to clean the first pass twice a day or even more frequently.

An excellent rule for determining the amount of steam used by a soot blower is this: To the gage pressure in lb. per sq. in. add 14.7; then multiply by the total area of all of the openings in the soot blower element in sq. in.; and lastly divide by 70. The result is the number of pounds of steam used per second. By applying this rule to the various elements installed on the boilers, it is a simple matter to determine the annual saving that can be effected as a result of timing the blowing operations.

Newark, N. J. W. F. SCHAPHORST.

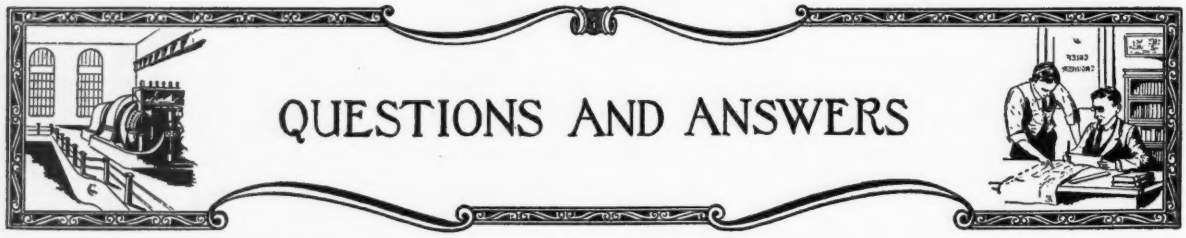
Can My Power Plant Afford a Soot Blower?

ASSUMING THAT a soot blower for the boilers should pay 25 per cent on one's investment including interest, depreciation and upkeep, you can closely figure the amount of money that you can afford to spend for a soot blower as follows:

Take the average flue gas temperature before installing the soot blower and from it subtract the temperature guaranteed by the blower manufacturer. Multiply this difference by 457. Divide the result into the heat value of your fuel. Then multiply by the present boiler efficiency in per cent before installing the soot blower. Add one to the result. Then divide that into the number of tons of fuel burned per year and we will call the result "A." Now multiply the number of boilers by 42 and call that "B." Subtract "B" and "A." Then multiply by the cost of fuel in dollars per ton, and lastly, multiply that result by 4. The answer is the amount you can afford for soot blowers.

In the above rule, it is assumed that 18 lb. of air are used per pound of coal as fired, that there are 6 blower elements in an average installation, the tubes are cleaned 4 times per day, the boiler is operated 300 days per year, and that the average rate of evaporation is 6 lb. of steam per pound of coal.

Newark, N. J. N. G. NEAR.



Heating Water With Steam Coils

How many square feet of pipe will be necessary to heat a given quantity of water to the boiling point, what time will be required and how many heat units if the cold water is 60 deg. F., room temperature 70 deg., steam pressure 80 lb. per sq. in., and the tank for heating the water is 3 ft. square, uninsulated and open at the top? Steam coil will be trapped. L. B.

A. You have not stated the amount of water to be heated, so we will assume 1500 lb., which will be the amount contained in a tank 3 ft. square by 2 ft. 8 in. deep. You also ask how many square feet of heating surface and how long to bring to the boiling point. This introduces two unknown quantities and we cannot solve the problem unless we decide on only one unknown value. If the time limit is given we can solve for the area of heating surface, or vice versa. The temperature of the room also introduces a complicated calculation which will be unnecessary for all practical purposes, so we must assume that as the water is heated there is no loss of heat by radiation or convection. The formula, then, for calculating area of heating surface is

$$S = \frac{CW\,(t_2 - t_0)}{Ud} \qquad (1)$$

where S = sq. ft. of heating surface; C = mean specific heat of fluid to be heated, for water = 1.0; W = weight of fluid to be heated, lb.; t_2 = final temperature of fluid to be heated; t_0 = initial temperature of fluid; U = mean coefficient of heat transfer for the entire surface, B. t. u. per sq. ft. per degree difference in temperature per hr.; d = mean temperature difference between the steam and that of the fluid to be heated (all temperatures in degrees F.)

It is definitely known that the quantity of heat passing through the heating surface is proportional to some power of the temperature difference at any instant; but the instantaneous temperature difference is indeterminate, consequently it is necessary to establish an average or mean temperature difference for the whole period. For accurate calculation the logarithmic mean is used; but in ordinary practice, the arithmetical mean is found by the following equation:

$$d = t_s - \frac{t_2 + t_0}{2} \qquad (2)$$

where

d = mean arithmetical temperature rise; t_s = steam temperature; t_2 = final temperature of fluid to be heated; t_0 = initial temperature of fluid to be heated.

Values of U are found in the accompanying table.

Heat Transfer—Submerged Steam Coils

Mean Temperature Difference	Coefficient of Heat Transfer — U		
	Iron	Brass	Copper
50	100	200	220
100	175	275	300
150	200	375	400
200	225	450	475
250	250	475	500

We can now assume 1500 lb. of water at 60 deg. F. to be heated to 212 deg. F. by means of iron steam coils with steam at 80 lb. gage pressure. Required to find the sq. ft. of heating surface.

First, solving for d, we get

$$d = 325 - \frac{212 + 60}{2} = 189 \text{ deg., mean temperature difference}$$

$$S = \frac{1500 \times 152}{219.5 \times 189} = 5.48 \text{ sq. ft. heating surface.}$$

This would be the equivalent of about 10.5 linear ft. of 2-in. pipe. The number of heat units would be: $1500 \times 152 = 228{,}000$ B. t. u.

Why the Engine Will Not Start

In the issue of June 15, a list of examination questions and answers is given and among these there is a question regarding the starting of a tandem compound engine. This was stated as follows: "A tandem compound engine will start all right from the bottom quarter, but will not start from the top quarter. What is wrong?"

There is a possibility that the question was not submitted exactly as given by the examiner for when a question comes through several different hands some part of it is likely to be changed slightly or even left out altogether. Taking the question as stated, however, the writer can think of three possible answers.

First: If the valve stem of the inlet valve of the head end of the high pressure cylinder should break in such a way that this particular valve could not open, the engine could not be started when the crank is on the top quarter without operating the valves on that cylinder by hand and blowing through to the low pressure cylinder and starting that way. We assume in all these cases that the engine runs over.

Second: Uneven adjustment of the releasing gear, if of the Corliss type of engine, might cause the latch to unhook on the head end of the high pressure cylinder thus releasing and shutting the inlet valve on that end before

half stroke, whereas, if this did not happen, the valve would be open nearly full stroke.

Third: If the engine was of the type of which the valves cut off the steam at half stroke when starting, it could not be started when crank is on the top quarter without working the valves by hand because, due to the so-

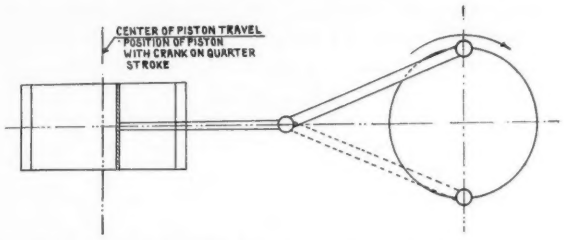


DIAGRAM SHOWS EFFECT OF ANGULARITY OF CONNECTING ROD

called angularity of the connecting rod, the piston would be a little past the center of its travel when the crank is on the top quarter. When the crank is on the bottom quarter coming back the piston will not have reached the center of its travel and the valve will still be open, but of course, will not remain open long when the engine is started, but might let in enough steam to carry the crank over the dead center when the other valve will open and complete the operation.

The accompanying diagram will help to make the answer in the last case clear.

Worcester, Mass. S. E. BALCOME.

Current Distribution in Edison 3-Wire System

IF AN EDISON 3-wire system has 10 lamps between the positive and neutral wires as shown, 6 lamps between neutral and negative and a motor taking 15 amp. across positive and negative wires, how much current will flow in each wire? Each lamp requires 1 amp. P. A.

A. As shown on the sketch, 25 amp. will flow through the positive wire as far as the lamps, each lamp will take

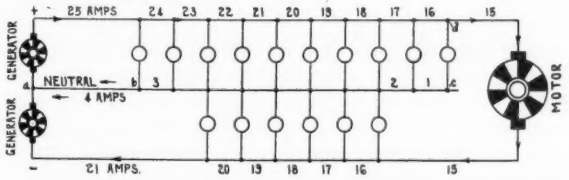


DIAGRAM SHOWING SLIGHTLY UNBALANCED LOAD ON 3-WIRE SYSTEM

1 amp. and 15 amp. will be left at d to flow to the motor and back through the negative wire. To this 15 amp. will be added the 6 amp. taken by the lower lamp bank, making a total of 21 amp. in the negative wire as shown. The difference, 4 amp., flows back toward the generator through the neutral.

With the six lamps on the negative side connected at other points between b and c of the neutral, the distribution of current in bc would be different from that shown. In any case, however, the neutral between a and b would be carrying 4 amp.

What Do the Cards Show?

ACCOMPANYING are two indicator cards taken from the high pressure cylinder of a cross compound engine immediately after overhauling. The cylinder is 25 by 48 in. with piston valves. The card shown by Fig. 1 was taken

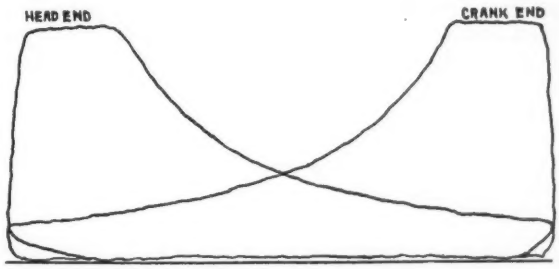


FIG. 1. INDICATOR CARD FROM 25 BY 48 IN. HIGH PRESSURE CYLINDER OF A CROSS COMPOUND ENGINE, AT 63 R. P. M., RECEIVER PRESSURE 3 LB.

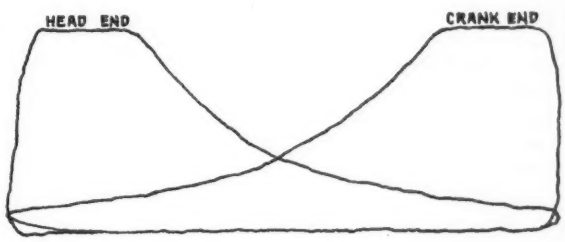


FIG. 2. INDICATOR CARD FROM SAME ENGINE AT 82 R. P. M., RECEIVER PRESSURE 18 LB.

at 63 r. p. m., while the one in Fig. 2 was at 82 r. p. m. Change in the low pressure cutoff between taking of the two cards accounts for the great difference in receiver pressure. Gage pressure 150 lb., 80 lb. spring in each case.

I shall appreciate criticisms and suggestions for improvement. R. H. M.

How Do You Figure the Rated Horsepower of a Motor?

I HAVE AN a.c. motor with the following specifications stamped on the name plate: 220 v., 24.7 a., 60 cycles, and 10 hp. I do not understand how they arrive at this power rating. By multiplying the volts by the amperes and dividing by 746 the horsepower of the motor should be obtained, yet when I do so I get the following:

$$220 \times 24.7 \div 746 = 7.27 \text{ hp.}$$

Why doesn't this check with the figure of 10 hp. given on the name plate? L. B.

A. You have failed to consider the power factor and the system of current distribution. We will assume that this is 3-phase and that the power factor is 0.80. We then have:

$$\frac{220 \times 24.7 \times 0.80 \times \sqrt{3}}{746} = 10 \text{ hp.,}$$

which checks with the manufacturer's rating.

Condensate from the World's Power Plant

ANALYZED FOR QUICK STUDY AND COMPARISON. BY WILLIAM SIBLEY

Buy Your Coal Now and Store It

During the latter part of June, leaders in the United Mine Workers and operators of anthracite mines will meet to discuss a renewal of the existing wage agreement. This confab will in no way affect the peace now being enjoyed in the bituminous fields under the Jacksonville agreement. The latter does not terminate until April 1, 1927.

What developments the June meeting will bring no one at this writing can say. Many of the better informed realize, however, that a strike in the hard coal regions is not only possible, but quite probable. In the event of a strike, it would take effect September first.

While anthracite plays a minor part in the country's power plants, a strike in that region will surely strengthen bituminous prices and now is the time to fill the storage yards. It is common practice to carry in storage from 6 to 10 per cent of the annual consumption. Just now, many men in an excellent position to know the status of the coal industry are instructing their managers to increase the storage of coal up to 25 or 30 per cent. Indeed, several large users of coal, such as gas producing companies, are assuring themselves an adequate supply of that basic raw material by purchasing a controlling interest in a mine. "Buy your coal now and store it" is an old story, but old or new, there never was a more advantageous time than now to lay in an adequate supply of fuel.

The coal industry is, without doubt, the most over-developed of all industries. Under full production it can produce two tons for every ton needed. This over-development is necessary because of the seasonal character of the industry—the wide fluctuation in demand. But it is this over-development that has nearly bankrupted the industry since the adoption of the Jacksonville agreement. In Illinois, 35,000 of the 90,000 miners are unemployed, the remainder work an average of two days a week. Indiana has 35,000 miners, 25,000 of whom are idle, the 10,000 working an average of one day a weak. This condition is similar to that of Central Pennsylvania, while in Ohio only one of every three miners is able to find work an average of 1½ days a week. To my knowledge only one large operating company made money last year. That was the Pittsburgh Coal Co., now operating less than half its mines, while owning more than one hundred. The Consolidation Co. and many others reported heavy losses.

One of the results of this unemployment is the desertion of many thousand miners who have left their trade to enter other lines of endeavor. Only a percentage of these men will return to the mines when reopened. Formerly, new workers were drawn from immigrants, but today we have practically no immigrants, due to existing laws. It will be difficult for many operators to get sufficient labor when they need it.

Back in 1912, when our population was smaller by many millions and when our industry was not so pretentious, the coal industry produced about 8,000,000 tons of "soft" coal weekly. In spite of the advance in population, the greatly increased industrial demands and our multiplied wealth, coal production thus far this year has been running considerably under 8,000,000 tons a week. The result is seriously depleted reserves the country over.

For some time we have been hearing much of the long range weather forecasts being made by scientists, experts and meteorologists. Dr. Abbott, Herbert J. Browne and the Smithsonian Institution in Washington have been studying the solar constant method of weather determination since 1905, and they have recently attracted considerable attention by their forecasts. Mr. Browne's forecasts for 1923, for instance (told 9 months in advance), proved 100 per cent accurate. Eighteen out of his 19 forecasts for 1924 proved correct. Last September, Mr. Browne said the spring of 1925 would be tardy in its coming, a bad one for small grains and fruit and accompanied by late frosts. He was right. He says our coming summer will be short and subject to wide variations in temperature. He believes frosts will come early in September and seriously damage the corn—that our coming winter will be long and very cold. British scientists, following entirely different lines of research, have arrived at substantially the same conclusions. Two South American countries have been employing the solar constant method of weather determination for a number of years with excellent results. Prof. Sernander of the University of Sweden states that he holds data which proves the coming of another "Fimbul period," which according to Norse history, is a "period of three winters in one with no summer intervening." If all of these men know what they are talking about, heavy demand will confront the mine operator.

The coal industry is fraught with difficulties—beset with serious problems. It is a wise buyer who gets his coal on the ground *now* while the present low prices prevail.

Evolution?

Two hundred and ninety-two years ago, the authorities in Rome sentenced Galileo to a short term in jail and imposed upon him the punishment of publicly reciting the seven penitential psalms once a week for three years. They did this because Galileo held to the theory that the earth moved 'round the sun. Such a theory was held to be rank heresy and "not in accordance with the Holy Scripture."

Ninety-seven years ago, the school board in Lancaster, Ohio, said to a society of civil engineers who had applied for the use of the schoolhouse: "You are welcome to use the schoolhouse to debate all proper questions. But such things as railroads and telegraphs are impossible and rank infidelity. There is nothing in the word of God about them. It is a device of Satan to carry the souls of the faithful down to hell."

Today we find another teacher haled into one of the courts of Tennessee because he holds to the theory of evolution. His persecutors say: "Evolution is in opposition to the Scriptures."

Personally we have little interest in the outcome of the present trial. We know both sides are financed by the American Civil Liberties Union. But we can't help wondering what people a hundred years hence will think of the 1925 Tennessee trial.

The first definition Webster gives for "evolution" is: "The act of evolving; development or growth." If that is what evolution means, our civilization must be fundamental.

It Is Time for Us to Wake Up

After November 4, last, when the majority of the voters expressed their convictions, there was a feeling that, "Coolidge is President and all's well with the United States."

Nothing could be farther from the truth. All is not well with the United States. Certainly all is not well with the world, in which the United States holds a prominent place.

Cable news from various parts of the world tells the story of the activities of the Third Internationale. Bulgaria is torn with insurrection (following the bombing of a cathedral which blasted the lives of 200 men, women and children). South Africa is experiencing riots, incited by agitators under the direction of Moscow. France, Italy, England, Portugal, Spain, India and other countries are having their own troubles. Iceland has sworn in every man between the ages of 20 and 50 to assist in the suppression of communistic agitation.

William Z. Foster, leader of the Communists in America, talked to an audience of 3000 in the Central Opera House, New York City on May Day, 1925. Little children and grown men, women and girls, 50,000 strong, sang the International or Hymn of Revolution, and cheered the advocacy of poisonous doctrine at May Day meetings in New York. A labor union leader's home was bombed by Communists in Gary, Ind., on the same day. Meetings similar to those held in New York were held simultaneously in Chicago, Cleveland, Seattle, Minneapolis, St. Louis, San Francisco and other industrial centers. People the country over are being taught to hate the Stars and Stripes and to despise the Constitution of the United States. In a mild, yet effective way, many of our churches, schools and colleges are, all unconsciously, aiding the spread of these destructive influences by teaching pacifism, internationalism, "industrial democracy" and the like.

We do not like emphasizing this subject. Would that it were not necessary. But when we remember that it took the murder of but a single prince to start the World War, we can't help but ask you to watch carefully the war clouds that are gathering across the seas. Not alone the Russian Communists, but the *world* communists, are getting ready rapidly.

A Tendency in the Right Direction

Some weeks ago I called attention, in these pages, to the rapidly increasing indebtedness accruing to the coming generation through the too frequent issuance of tax-exempt bonds. It was the contention in my editorial that we were developing the expensive habit of buying on borrowed money and that for the most part the money was borrowed from our children, since they were the ones on whom the obligation would fall, the maturity dates being from fifteen to twenty years hence.

The idea was in no wise original. For several years, some of the country's best economists have been talking about the tendency of local and state governments to plunge themselves into debt through the medium of long term bond issues. Not long ago our President voiced a warning against the piling up of local debts while the federal government was bending every effort to curtail expense and pay off the federal debt.

Whether or not the warnings of the past few years are beginning to be heeded no one can be sure. We do know, however, that during the month of May the Michigan legislature turned down three bond issues, not by close votes but by very decisive majorities. And, singularly, these refusals affected the heretofore sacred cause of "education," for each of the voted-down bond issues covered a new high school, calling for a heavy investment.

Whether or not the Michigan legislature was right in its action, few would presume to say. We believe, however, it is a step in the right direction, for state and local taxes are now reaching a point where close scrutiny and serious consideration must be given every measure that would make for heavier indebtedness. Figures, better than anything else, show the increases in taxation, and we here set forth the figures covering ten states.

STATE TAX (PER CAPITA)

States	1912	1922	Percent Population Increase
Iowa	$16.45	$43.36	8.1
Kansas	16.55	38.83	4.6
Maine	11.86	28.83	3.5
Mississippi	5.28	17.12	—0.4
Nevada	24.02	65.47	—5.5
New Hampshire	15.98	33.71	2.9
Vermont	11.17	26.07	—1.
West Virginia	7.67	25.39	19.9
Wisconsin	15.23	40.45	12.8
Alabama	4.45	9.40	9.8

Only five states in the Union (Arkansas, District of Columbia, Massachusetts, Montana and New York) have failed to increase the per capita tax more than 100 per cent during the years between 1912 and 1922.

The refusals on the part of the Michigan legislature to approve bond issues affected the erection of new schools. It is interesting, in this regard, to know that the per capita investment in school property in Kalamazoo, Michigan, increased from $0.30 to $15.38 in the five years from 1917 to 1922. Other cities, cited as typical, are as follows:

SCHOOL PROPERTY—PER CAPITA INVESTMENT

City	1917	1922
Columbus, Ohio	$0.01	$4.70
Atlanta, Ga.	.16	5.13
Memphis, Tenn.	.10	3.14
Reading, Pa.	.06	3.46
Schenectady, N. Y.	.15	10.02
Harrisburg, Pa.	.05	4.91
Troy, N. Y.	.07	3.23
Racine, Wis.	.08	2.29
Tampa, Fla.	.13	4.05

No city in the United States of over 100,000 population has failed to increase its school property investment at least 200 per cent faster than the school attendance, *in the last 5 yr.*

The Michigan refusals may or may not indicate that the taxpayer is growing weary of piled up debt and constantly mounting interest payments. If it does indicate any such thing, we have before us a symptom of returning financial health.

EDITORIAL COMMENT

That Superiority Complex

"Forget for the time being that you ever went to college," is the advice given by the National Industrial Conference Board, in a recent statement, to all young men who are graduating at this time from the technical colleges of the country and expect to enter industry. This advice is prompted, according to the statement, by the general feeling throughout industry that the young technical graduate is too impatient for promotion, that he overrates the value of his education and underrates the importance of small details of practice, that he is often unwilling to work with his hands, that he has little understanding of business and that he does not know how to associate with common workmen so as to gain their respect or co-operation.

These criticisms are made over and over by executives, both college and non-college. Furthermore, the report brings out the fact that there are not enough strictly technical jobs for all the graduates from engineering courses. Many of the important positions in industry require knowledge of human and economic laws, as well as of engineering and industrial details.

This whole subject is entirely too big to be treated here in detail. It should be remembered, in the first place, that the majority of college trained industrial executives probably had, at some time in their lives, the same "superiority complex" that they object to in the college man of today. Nothing but hard, bitter experience could knock it out of them, and it will do no good to try to shield the youngsters from that experience. If a college man cannot stand the blow of discovering that the world is not his own personal oyster, then there is little hope for him in industry.

On the other hand, industrial executives should remember that a large proportion of all technical graduates are not fitted, either by temperament or by native intelligence, for engineering work. Among these are many who have jobs waiting for them when they leave the engineering college, in the organizations of families and friends. These are tragic figures—the products of nepotism. Even more tragic is that group of mediocre minds, sent to the technical colleges because, by some fortuitous circumstance, the money was available and because they didn't want to be doctors or lawyers, or had built a radio set and thereby displayed true engineering genius. Then, crammed for four years with abstruse information about engineering design and theory, passing their courses by the skin of their teeth, they come forth with a false opinion of their value to industry and their position in it. By telling the truth about the functions of the engineer and his real place in industry, as the National Industrial Conference Board is doing, this group of mediocrities will be discouraged from going to college in the first place.

We have a strong suspicion that, as long as engineering colleges exist, the advice of the Board to graduates—to forget for a while that they ever went to college—will go unheeded by the very men who need it most. Like all other common-sense advice, its truth must be battered into them. The ones that survive the battering will be of some value to industry.

There still remains, however, a large body of technical graduates of real ability who are not obsessed with the "superiority complex." Too often, because of their willingness to get their hands dirty and to learn from the bottom up, advantage is taken of them by some of these same executives who criticize them, by keeping them in detail jobs which they perform well because they are ambitious, but in which they are in danger of being submerged. Nevertheless, it is from this body of unassuming, ambitious youngsters that our future executives will come. Industry as a whole, we feel, must learn what to do with a good college man when he appears.

Personality in Engineering

Engineering is often, though erroneously, regarded as being an exact science. This conception no doubt arises from a consideration of the natural laws upon which the science of engineering is based, and from this viewpoint perhaps, it is justified. We know definitely that when a certain uniform electric potential is impressed across the terminals of a circuit of fixed resistance, a current of certain definite value will flow. Ohm's law which expresses this relation between current, voltage and resistance in an electric circuit is a fundamental truth, the very bed rock, in fact, of electrical engineering and we can at all times rely upon it.

Engineering, however, is concerned with the application of natures laws to the solution of practical problems, and when considered in this light it loses all the aspects of being an exact science. It is in the application of the natural laws that the variables creep in and that the personal equation manifests itself.

Put the same engineering problem up to a half dozen engineers. Will the results submitted by these six men be exactly the same? By the laws of possibility and chance they may, but the chances are far greater, that they will not. Certain fundamental principles will be observed and adhered to by all but the method in which the solution is brought about will differ as widely as the men themselves differ in personality.

The truth of this assertion is well illustrated in the design of Crawford Avenue Station described in this issue. Here was a generating station planned for an initial installation of three generating units, each of approximately 50,000 kw. capacity, working side by side under exactly the same conditions. The design of these three machines was put up to three different manufacturers, two in America and one in Europe, each manufacturer being awarded the contract for one machine. Now, anybody contending that engineering is an exact science would no doubt have expected the three machines, as finally installed, to be exactly alike both in principle and design. Were they?

If any reader is still unfamiliar with the interesting details of these three machines, we suggest that he turn to

the leading article in this issue for full particulars. Today the machines are installed and in operation, side by side, but it is safe to state that no three turbogenerators ever built for the same operating conditions and approximately the same capacities were ever more unlike, mechanically.

This fact, to our mind, is one of the most interesting things at Crawford. It illustrates not only the high degree of excellence attained by the various manufacturing companies in their particular principles of design, but it shows personality in engineering, and that, in engineering, counts for quite as much as does personality in human beings.

The Muscle Shoals Problem Is Solved

In a recent letter to the chairman of the Muscle Shoals Inquiry Commission, William Green, president of the American Federation of Labor, gave utterance to the following remark: "Since such large government funds have already been expended, it would, in my mind, be a highly desirable and advantageous experience to continue Muscle Shoals as a government undertaking and experimental development to set standards for private undertakings and records of costs."

We should like to know what experimental work of benefit to private undertakings will need to be done at the Wilson Dam hydro-electric plant that has not already been done.

Government and Industry

More business in government, less government in business has been a demand much reiterated during recent years. Apparently this is having an effect in Washington as evidenced by the attitude of administration heads and department policies.

Results of the Budget Bureau activities and the campaign for economy in departments are shown in reduced taxes, talk of still further reduction, and reports of departments and bureaus in which they enthuse over economies effected. And the tendency is to rearrange tax schedules so that they will interfere as little as possible with the progress and activity of the country's industries. It is a pity that as much cannot be said, in all cases, for the activities of state tax departments.

Factional and class legislation and political lobbying are not in favor at Washington. Real helpfulness to industry as a whole and to the whole of each branch of industry is the end desired. Isms, fads and palliative nostrums are barred. Help industries to help themselves is the fundamental basis.

Reduction of complexity in manufacture and marketing by standardization of sizes, materials and methods is one advance that has been encouraged, with great economy to many industries.

Recent decision with regard to the activities of trade associations and the intent of the Department of Justice to help them find their proper field are helping to put cooperation in industry on a safe and workable basis.

Results of government research are being made available to all who can use them and assistance in solving problems of special industries (not of individual firms) is readily available.

Government restriction and supervision are being considered as a means only to insure the conduct of business for the best interests of the country as a whole, not as a method of hampering and harassing industrial activity. Business organizations are given credit for honest intent until the contrary is proved.

These are the impressions one gets from observation of activities of the government bureaus and contact with officials. Cooperation between government and industry seems to be making real and substantial progress.

What Is a B.t.u.?

Recently considerable interest has been revived in discussions of the Brünler boiler. Although the operation is unique and a rather startling departure from the orthodox method of producing steam, the really remarkable feature of the apparatus lies in the claim of the inventor that he has repeatedly obtained an evaporation of 20 to 24 lb. of water when burning oil of 16,200 B.t.u. Expressed in our usual terms of efficiency, this indicates the seemingly paradoxical condition of obtaining a recovery of 23,290 B.t.u. from the 16,200 B.t.u. originally found in the oil. This would be equivalent to an efficiency of 144 per cent.

Energy appears to have been taken from some external source or we might say mysteriously created. Yet we know that this cannot be true and we must, therefore, go back to the original conditions, under which evaporation was effected, for our answer.

Herr Brünler states that his paradox may be explained by the action of ultra-violet rays from the burning oil. In ordinary boiler practice, when using a furnace, energy from this source is lost but with flame in direct contact with water, the energy of these rays cannot escape and is therefore absorbed by the water.

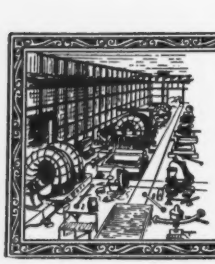
This means that our accepted value of a British thermal unit may be wrong and that under auspicious conditions a pound of fuel will produce much more energy than we now think. The proposition seems worth investigating, yet it has been over eleven years since news of the Brünler boiler was first published in this country and still no one seems to have given it serious consideration.

Recent experiments in the burning of powdered coal disclosed the astounding fact that under certain conditions 750,000 B.t.u. could be released in a single cubic foot of furnace volume instead of only 20,000 to 30,000 B.t.u., as had ordinarily been done. This is so remarkable that we think it highly important for further and more careful investigation in this direction.

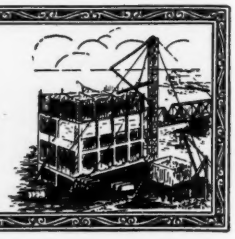
Step by step, with perhaps years intervening, we are slowly wresting from nature, her inmost secrets and often learning that our old ideas have been wrong. For centuries men clung to the Ptolemaic theory that the sun revolved about the earth, but Copernicus finally startled world with his now positively proven law that the sun is the center of planetary movement. It was a revolutionary idea but men finally came to accept it without question and so who knows but that someone will find that our pound of oil or coal really contains 1½ to 2 times as much energy as we now suppose.

MAIL ORDER houses are monuments to the value of the written word. Also, they are silent testimony to the impotency of the sales language used over the retail counters of America.

OVER THE luncheon table recently, Glen Buck said: "Ignorance is never bliss—but just hard work and low wages."



POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS



East River Plant to Have Nine 60,000 kw. Units

NEW PLANT OF NEW YORK EDISON CO., OF 700,000 KW. ULTIMATE CAPACITY, INCORPORATES MANY REFINEMENTS AND WILL BE ONE OF LARGEST IN THE WORLD

WHEN THE East River Station of the New York Edison Company, now under construction, is completed, New York City will have one of the world's largest electric generating stations. This station, which will cost in the neighborhood of $50,000,000, will have a capacity of 700,000 kw. Operated at full capacity, it would be capable of serving any state in the United States except New York. While the station is designed to enable the company to serve the increased population of New York City in 1930, it represents only a step in the company's plans to equip itself to serve the much larger growth of population expected in the metropolitan area by 1950, when, according to estimates submitted to the Committee on Regional Plan of New York and Its Environs, 16,000,000 persons will reside in this area.

The new station will be seven stories high, 207 ft. wide and 1100 ft. long—the equivalent of four average city blocks. It is being built on an irregular tract at Fourteenth Street and the East River. It is expected that the building itself, which will cost approximately

Photograph by Ewing Galloway, N. Y.

CONCRETE AND PILING IN BED OF EAST RIVER FORM PART OF FOUNDATION FOR NEW EAST RIVER STATION. WORK ON THIS FOUNDATION IS SHOWN IN PROGRESS INSIDE A COFFER DAM

$12,000,000, will be completed by the end of 1925, and that the initial installation of generating equipment will be completed in the spring of 1926. The station was designed by Thomas E. Murray, Inc., in consultation with the officers and engineers of the New York Edison Co.

Nine turbo-generators will be installed, each having a capacity of 60,000 kw., which is 10,000 kw. greater than the capacity of the largest single unit now in operation; additional equipment will give the station a total capacity of 700,000 kw. The contract for the first two of these machines has been given to the General Electric Company, Schenectady, New York. Each of the nine generators will weigh 1,182,500 lb. As it is a physical impossibility to ship these units complete, they will be assembled at the East River Station. Even then it will be necessary to handle weights up to 185 T. and for this purpose two traveling cranes, each having a carrying capacity of 200 T., will be installed in the turbine room. From the East River, 800,000 gal. of water a minute will be pumped through the condensers.

Coal will be brought to the plant in ocean-going steamers of 5000-T. capacity. Traveling towers along the waterfront will unload the boats at the rate of 500 T. per hr. Each tower will be equipped with a 2-T. bucket which will make two round trips a minute, lifting the coal from the ship and dumping it into one of the crushers to prepare it for the furnaces. From that point the coal will be conveyed on belts through weigh-bins to bunkers immediately in front of each of the boilers.

Steam will be supplied by 10 boilers, each with a capacity of 1550 hp. at normal rating. But through the use of water-cooled side walls, it is expected that the boilers will be operated at unusually high ratings and efficiencies. Above the boilers will be located the economizers for cooling the escaping gases down to the lowest possible temperature before discharge into the atmosphere. Steam will be supplied to the turbines at 350 lb. pressure and 700 deg. F. total temperature.

Fire Observer Permits Thorough Furnace Inspection

FREQUENT OPENING of boiler furnace doors in an attempt to inspect the condition of the fire is in most cases worse than useless, because the heat and glare blur the operator's vision and, at the same time, cold air is let into the furnace. Gages will advise the boiler operator when conditions are not right in the furnace, but they have their limitations. Gages cannot tell that there is a hole in the fire or that the fire is too thick or too thin. They cannot tell where the hole is, or the location of a clinker. To allow frequent and deliberate inspection of the fire in any type of boiler or industrial furnace, the Vastine Furnace Fire Observer has recently been placed on the market.

This device is designed for use either with natural draft or forced draft furnaces, slight differences in design being necessary in the latter case. Fig. 1 shows how Type W-N is installed for natural draft operation. It is so designed and baffled that the draft through the furnace creates air circulation within and around the observer, as well as between the two glass doors, thus keeping the temperature of the observer at a minimum. An arch is sprung over the top of the opening, as shown, to divert slag.

As shown in the illustration, the observer consists essentially of the frame, equipped with air controls, cooling fins and grids, and the two glass doors with their ventilating

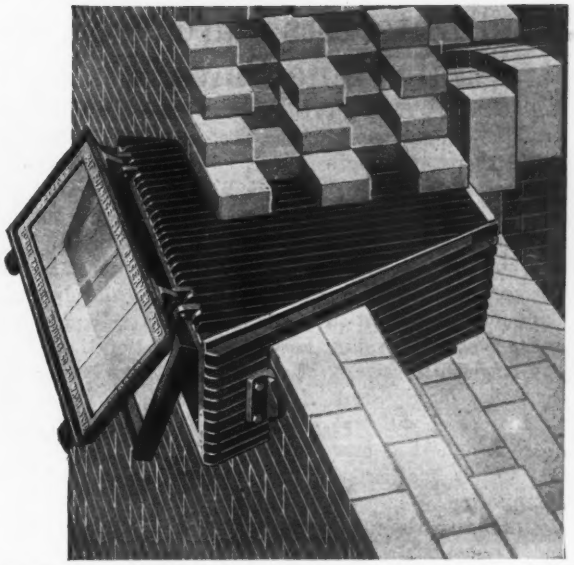


FIG. 1. TYPE W-N OBSERVER, INSTALLED FOR NATURAL DRAFT OPERATION, REQUIRES NO SPECIAL SETTING EXCEPT THE ARCH AS SHOWN

spaces. The grids absorb radiant heat from the fire, and air, passing between the doors and through the grids is heated before going into the furnace. Details of the doors, which are much the same on both types, are shown in Fig. 2. With natural draft, air enters through air ports I (which close automatically if the inside door is opened) flows through H and down between the doors to G, whence it passes through the grids into the furnace. If forced draft is used, a pipe from the air duct is connected at K, the pressure opens a butterfly valve and closes part L and air then passes through ports I as before. If for any reason the forced draft is off, the valve closes K, opens L, and air circulation through the observer is maintained by natural draft.

The opening at the rear of the observer is 5½ in. by 5½ in.; the door opening is 24 in. by 9 in. This gives a range of vision equivalent to an opening in a wall of 24 in. by 10 in. In addition to Types W-N and W-F mentioned above, Type D is manufactured in a smaller size for fastening to the furnace door or inspection door. The Vastine Furnace Fire Observer is distributed by the Vastine Sales Corp., 205 W. Harrison St., Chicago, Ill.

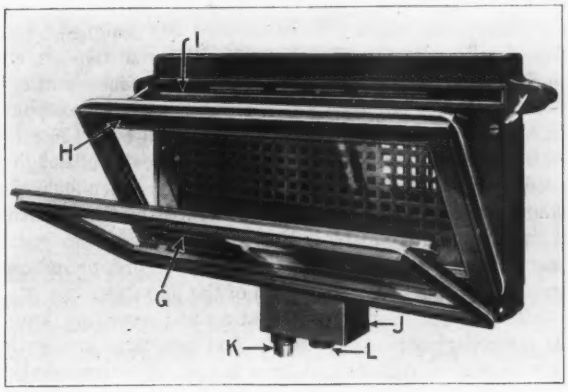


FIG. 2. AIR COMING FROM PORTS I THROUGH H KEEPS GLASS DOORS COOL AND IS WARMED BY GRID BEFORE ENTERING FURNACE

Insull Interests Purchase Central Maine Power Co.

MIDDLE WEST UTILITIES CO. has agreed to buy the common stock of the Central Maine Power Co., 25,000 shares, for approximately $140 a share, according to an announcement by Walter S. Wyman, president of the Central Maine Power Co., after a conference on June 4 with Samuel Insull and Martin Insull. The Insull group plans to expend about $20,000,000 in improvements and expansion of the company's business, and has already made plans for the completion of the Clark's River Dam on the Androscoggin River, near Lewiston, at a cost of $4,000,000. The Augusta Trust Co., of Augusta, Me., has been made depository for the stock of the Central Maine Power Co. Final transfer will take place about July 1. Mr. Wyman will be retained as president of the Central Maine Power Co., and in addition will hold office in the Middle West organization.

In addition to the plants in Maine, New Hampshire and Vermont, already controlled by the Insull interests through the National Light, Heat & Power Co., it is reported that they are conducting negotiations for the purchase of other large power interests in New England. They already own plants of the Twin State Gas & Electric Co., and of the Berwick & Salmon Falls Electric Co., as well as a 33,000-v. transmission line from Burlington, Vt., to Arlington, Vt. Negotiations are also under way for the purchase of the Manchester Light, Traction & Power Co., Manchester, N. H., one of the largest in the district. Several millions of dollars have already been spent in improving the various properties.

Telemetering Aids Load Dispatching

IN THE ART of remote metering, a new development is exemplified in a plan recently decided upon by the Central Illinois Public Service Co. This company is faced with the necessity of recording the load of its Muddy Power station, near Harrisburg, Illinois, at its Grand Tower station, approximately 60 mi. distant. It is also necessary to indicate the load of both these generating stations at a switching station at West Frankfort, approximately midway between the two. In addition, an indication of the generating station loads is necessary at the load dispatcher's office at Marion, about 15 mi. south of West Frankfort. All metering is done over the company's private telephone lines.

The system which is to be adopted was designed by the General Electric Co. Totalizing watthour meters are employed at the generating stations, which, by means of contacts, originate impulses which are sent over the telephone lines. By means of condensers and retard coils these impulses are kept out of the telephone circuit, although a modification of the ringing system of the telephones was found necessary. The impulses generated by the totalizing watthour meters will be indicated and recorded on instruments known as telemeters. These will record, or indicate, in direct proportion to the speed of the impulses.

This system of remote indicating and recording, known as telemetering, is expected to find extensive application among central stations and large industrial activities where it is desirable to indicate or record the load of various sections of a power transmission system at one or more remote points.

Death of Clifton H. Wheeler

CLIFTON H. WHEELER, former Vice-President and General Manager of the C. H. Wheeler Manufacturing Co., died on May 29. Mr. Wheeler was born June 25, 1856. Owing to the death of his parents when he was quite young, Mr. Wheeler's school days were interrupted and at the age of 15 he started working in the importing house of Lawrence Giles & Co., in New York. Here he advanced quickly and later formed the partnership with an old time stevedore under the firm name of Wilson & Wheeler.

In 1888 his brother S. Merriam Wheeler, who was a marine pump expert and engineer, showed him the advantages of the surface condenser for stationary practice and as a result he left the loading and unloading of ships to devote his entire time to condensers. Success was forthcoming and after much hard work he organized the Wheeler Condenser and Engineering Co. in 1891, serving as president and general manager until 1904. That the business was established on a firm basis and during an exceptionally trying period of business in this country was due to his foresight in developing the condenser field in Great Britain and her Colonies.

In 1905 Mr. Wheeler took charge of the bankrupt pumping engine plant, the Barr Pump Co., of Philadelphia and resumed once more the building up of another condenser concern, the C. H. Wheeler Co. to develop new and improved types of condensers for higher vacuum. He introduced successfully the reciprocating suction valveless wet vacuum pump, the rotary positive displacement wet vacuum air pump, and the hydraulic entrainment air pump, which was designed and developed at about the start of the war in Europe in 1914.

In all business associations, Mr. Wheeler has had the affection and esteem of his employes. For his associates he always had available loyal men who found by close association with him that he appreciated their efforts and rewarded them accordingly.

Until about two and a half years ago when he suffered a stroke, Mr. Wheeler was a member of numerous clubs and societies, but from that time until his death, was inactive and withdrew his membership from all organizations to which he belonged.

Elbert C. Fisher Dies Suddenly

ELBERT C. FISHER, vice-president and general manager of the Wickes Boiler Co., Saginaw, Mich., died on Monday, May 18, after a short illness.

Mr. Fisher was born January 1, 1865, in Scranton, Pa. He prepared for college in the public schools of Scranton and in 1890 graduated with honors from Cornell University, where he was a member of the Kappa Alpha society. From 1895 to 1907, he was in charge of the Boiler Department of Wickes Bros. and in 1907, when the present Wickes Boiler Co. was organized, he became its vice-president and general manager. He was vice-president of the American Boiler Manufacturers' Association, a member of the Council of the A.S.M.E., and was on its Boiler Code Committee, at the same time acting as vice-chairman of the Michigan State Board of Boiler Rules.

Mr. Fisher was regarded by his fellow members of the profession as one of the country's leading engineers in the steam boiler field. In personality he was of a retiring disposition, often avoiding contacts aside from those of his

profession and home. Yet, in public matters, he was always ready to give the services of his trained mind and in a quiet way he played an important part in the industrial activities of Saginaw.

News Notes

THE WEBSTER MFG. CO., Chicago, Ill., announces the appointment of L. A. Scheck as manager of its Boston sales office at 902 Oliver Building, Boston, Mass.

J. LUCIEN JONES, who has been with the Moss-Chase Co., Buffalo, N. Y., for the past 8 yr., is now advertising manager with the Andrews-Bradshaw Co., Pittsburgh, Pa., sales managers for the Tracyfier.

JOHN S. S. FULTON, of Baltimore, Md., assumed charge on June 1 of the Stoker Department of the Marion Machine, Foundry & Supply Company. George L. Sharp, for six years general comptroller of the same company, has been made manager of the Scottdale plant of the company.

GRINNELL CO., INC., sales subsidiary corporation of the General Fire Extinguisher Co., of Providence, R. I., announced on May 16, the completion of arrangements to open a branch in Minneapolis, located in the office and warehouse property at 240 Seventh Avenue, South. T. T. Cash, who has represented the Grinnell organization in the Twin City territory for several years, will be in executive charge of the establishment, which will serve the heating and building trades of the northwest.

THE BROWN HOISTING MACHINERY CO. has just made arrangements for the production of a rotary steam engine developed by Baker Motors, Inc., whose research and development laboratory in Erie, Pa., has just been moved to Cleveland, Ohio, with executive offices in the Union Trust Building. This rotary steam engine has been on an experimental basis for the past few years, but announcement has been made that an extensive equipment of machinery for the commercial production of the engine has been purchased by the Brown Hoisting Machinery Co.

CHARLES M. RING, formerly works manager of the Allied Steel Castings Co., Harvey, Ill., has been appointed assistant director of the Electric Steel Founders' Research Group, succeeding W. J. Corbett, who recently resigned to become secretary-manager of the Steel Founders' Association of America. During the past 15 yr., Mr. Ring has been connected with the American Steel Foundries, the Commonwealth Steel Co., the Illinois Steel Co., the Laclede Steel Co., and the Ohio Steel Foundry, prior to his connection with the Allied Steel Castings Co. He is a member of the American Foundrymen's Association and the American Society for Testing Materials.

BYLLESBY ENGINEERING & MANAGEMENT CORP. is remodeling the steam plant of the Northern States Power Co. at LaCrosse, Wis. Two old 400-kw. turbo-generators are being removed and the location of the present 2500-kw. unit will be changed to make room for a new Westinghouse, 5000-kw., turbo-generator with a 12,000-sq. ft. Worthington condenser. A 30-T. Whitehead crane is also being installed. Changes in the stoker accessories and boiler feed lines are also being made H. W. McArthur, of Byllesby Engineering & Management Corp. is superintendent of construction and Carl A. Newmann is acting chief engineer of the plant.

THE INTERSTATE POWER CO., Dubuque, Iowa, is arranging an early sale of 30,000 shares of preferred stock, a large part of the proceeds to be used for the construction of a new generating plant at Clinton, Iowa, and the enlargement of the present power plant at Dubuque. The work will include the construction of a 66,000-v. transmission line between the two plants.

W. R. MASON, one of the pioneers in the electric railway supply business, and during the past two years in the sales department of the Dearborn Chemical Co., operating out of the New York office, died after a short illness on May 2. Mr. Mason was born in Bridgeport, Conn., October 25, 1851. He became associated with the Sprague Electric Equipment Co. at Chicago, Ill., in 1890, later forming the Electric Merchandise Co., which company then took over the supply business of the Sprague companies. Mr. Mason was also identified with the automobile truck industry and during the early development of it was connected with the White Co., Packard and Mack International Companies. He is survived by his widow, Emma Van Voorhis Mason, and two sons, Edward R. Mason of New York, and Herbert E. Mason, of Chicago.

REPUBLIC FLOW METERS CO., of Chicago, announces that W. W. Barron, formerly of the Chicago office, is to take charge of a factory branch office to be opened by the company in the Bramson Building, Buffalo, N. Y.

THE COMAL POWER CO. is now constructing at New Braunfels, Tex., a new power plant, the ultimate capacity of which will probably be 100,000 kw. and the first unit of which will probably be 25,000 kw. It is expected that the plant will be in operation November 1, 1926. It is located about 30 mi. north of San Antonio, at the junction of two rivers whose flow is sufficient to supply condensing water without resorting to the use of a spray pond. A 66,000 v. transmission line is now being built to San Antonio to supply the San Antonio Public Service Co. with power from the new plant. This transmission voltage will be increased at a later date.

THE ROCHESTER, MINN., ELECTRIC LIGHT PLANT is now installing a 2000-kw., General Electric, multi-stage turbo-generator, with a Westinghouse 4500-sq. ft., condenser. The use of such a large condenser is necessary because for 2 mo. of the summer the condenser water has a temperature of 85 deg. or more. The turbine is equipped with bleeder connections for feed water heating and for supplying heating steam for the plant. The present capacity of the plant is 1750 kw., but it is expected that the peak load this year will reach 2400 kw. The city also has a 1900-kw. hydro-electric plant, 17 mi. north of Rochester, on the Zumbro River. The steam and hydro-electric plants are connected to the system in such a way that the steam units will be able to supply the system in case of trouble. The plant extension was designed by C. G. Hadley, Superintendent. Mr. O. G. Blazing is chief engineer in charge of operation.

SALE BY FRANK J. GOULD of his interest in the Virginia Railway and Power Co. was announced recently by a syndicate which has just brought negotiations to a successful close. The syndicate consists of Stone & Webster, Inc., Chase Securities Corp., Blair & Co., Inc., and Blodget & Co. The new property has a generating capacity of 140,000 hp., which includes both steam and hydro-electric plants, and owns valuable undeveloped water power sites.

It furnishes electric light, power and street railway service to a total of over 450,000 people in Richmond, Norfolk, Petersburg, Portsmouth and other communities, and does the entire gas business in Norfolk. The gross earnings in 1924 were over $10,000,000. The purchase also includes the Spotsylvania Power Co., serving Fredricksburg and owning valuable water power sites on the Rappahannock River. The properties will be under the executive management of Stone & Webster, Inc. of Boston, Mass.

Books and Catalogs

HENDRICKS COMMERCIAL REGISTER, 2522 pages, 33rd edition, 1925; 8½ by 11¼ in., cloth; Chicago, Ill.; price $12.

This book, the latest edition of which is now ready for distribution, constitutes an unusually complete and convenient reference volume of business organizations and their products, compiled especially for men who buy or specify materials of every description used in manufacturing, contracting, architecture and all branches of engineering.

In the first pages of the volume is a section giving alphabetically the headquarters addresses and distributors' offices of thousands of companies, covering the whole industrial field. This is followed by an index to the Classified Products section. The latter section, of 1780 pages, lists products of every nature from abrasives to zirconium, giving under each one the names of manufacturers or distributors of it. One of the most convenient parts of the book is the fourth section of trade names, in which, if the trade name of a given product is known, the name and address of its manufacturer can be found. In short, this is probably the most complete directory of American products in existence and it deserves a prominent place on the bookshelf of every man who has occasion to purchase or specify materials for industrial use.

CAPACITANCE MEASUREMENTS, inductance measurements and magnetic testing are the subjects discussed in Catalog No. 10, just issued by Leeds & Northrup Co., Philadelphia, Pa. Various types of capacitance and inductance bridges are described, as well as the Ayrton-Perry inductometer, and ballistic and other types of galvanometers and accessory apparatus. For determining the standard magnetic data, the Burrows permeameter and the Epstein core loss apparatus, both described in the A.S.T.M. test specifications, are listed. In some cases, the method of using the instruments is discussed in this catalog, but in others the uses to which the instruments may be put are so numerous that the reader is referred directly to various standard textbooks, as well as to the publications of the Bureau of Standards.

"GARLOCK PACKING SERVICE" is the title of a handsome book of 176 pages just off the press. Packing lies in our thought mostly as a part of the humdrum work of the power plant, but here we have its functions, its qualities and the service behind it presented in a form that attracts and holds attention. Each kind of packing is presented in an illustration showing its real color, with a description of how it is made, what materials are used and how and why they are combined into certain forms. Also the text tells for what service each type is intended and how to use it to best advantage. All types are included, coil, sheet, ring, gaskets and metal, as well as pump valves and valve discs, and an addendum follows of tables of engineering data. The book, catalog A-1925, is sent out by the Garlock Packing Co., of Palmyra, N. Y., and will be a useful as well as beautiful addition to any engineer's working library.

THE FALK CORP., of Milwaukee, Wis., is sending out a bulletin on Falk herringbone gear speed reducers. Various types of double and single reduction units are discussed and the catalog contains photographs illustrating some of their applications. Dimension tables of the various units are included for the use of the designer.

THE BRISTOL CO., of Waterbury, Conn., describes in a recent booklet a new type of gas-filled recording thermometer, employing nitrogen gas under pressure in the working system. All temperature ranges between 60 deg. below zero and 1000 deg. F. are covered by these gas-filled recording thermometers. If it is required to record low temperatures, a patented compensator is used, which corrects the atmospheric temperature at the instrument. The catalog gives details of construction and interior arrangement of these instruments, together with a price list.

THE HANSEN ARC WELDING GENERATOR is described in a bulletin just issued by the Northwestern Mfg. Co., Milwaukee, Wis. The method of eliminating the need of stabilizers is discussed, together with the mechanical construction of the machines. Some general comments on the welding of various metals are also included. Two ratings of Hansen welders are being built; one with a current range from 60 to 350 amp., intended mainly for metallic electrode work, the other with a current range from 90 to 400 amp., for both metallic and carbon electrodes.

COMBUSTION ENGINEERING CORP. has just published a booklet entitled "Report of Evaporative Tests on Boiler No. 1, Power House No. 1, River Rouge Plant of the Ford Motor Company." This booklet describes in detail the methods used and the results obtained in a series of eleven tests made on a boiler equipped to burn either pulverized coal or blast furnace gas or both. Many reproductions of drawings and graphs, made by the test engineers, are included, as well as a series of photographs showing details of the boiler equipment. The tests were made by test engineers of the Combustion Engineering Corporation in cooperation with the engineers of the Ford Motor Co.

NATIONAL VALVE & MANUFACTURING CO., of Pittsburgh, Pa., is sending out general catalog No. 6. This new catalog contains not only detailed information concerning the various types of pipe, valves, fittings and accessories manufactured by this company, but also considerable material of general engineering interest. Besides the usual dimension tables, there are diagrams of various kinds and photographs of miscellaneous fittings. All types of pipe and fittings are described for pressures up to 350 lb.

THE "MODEL D" MEGOHMER is described in Bulletin 130, just received from Herman H. Sticht & Co., of New York. The operation of this instrument is based upon the voltmeter method of insulation resistance measurements, the movement being of the high-resistance D'Arsonval type, with a resistance of 120,000 ohms. A double scale permits using the instrument not only as a direct megohmmeter but also as a voltmeter. The instrument includes a self-contained generator of the folding type, fitting into a recess in the cover.